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WORKING PAPER

EARTH RESOURCES OBJECTIVES AND MEASUREMENT REQUIREMENTS

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April 20, 1970

This paper should be considered as preliminary information and should not be referenced in formal documents.

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SUMMARY

Information about the data requirements of possible users of Earth Resources information as obtained from satellite-borne sensors has been gathered from a variety of sources, including discussions with representatives of key government organizations. From among the large number of proposed tasks whose achievement could be assisted by satellite-obtained information, a group of 29 objectives has been selected which have fairly well defined measurement requirements and reasonable evidence of feasibility. Each of the 29 objectives so selected has been described and values of their measurement requirements, as found in the information sources or estimated when necessary, documented in a series of "Objective and Measurement Descriptions." In addition, the measurement requirements pertinent to various candidate sensor systems and those pertinent to orbit selection have been summarized in tabular form. The material presented provides a single source of information on Earth Resource objectives and requirements which should be useful in a variety of mission analysis studies.

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INTRODUCTION

The possibility of obtaining information about the natural and cultural resources of the Earth from orbiting satellites has been recognized for some years. This possibility has generated increasing interest as more scientists and managers who are concerned with the Earth's resources have become aware of the potential of such information for increasing the understanding of resource problems and for increasing the scope and efficiency of resource management. Many of the decisions that must be made require information about conditions that exist over large areas of the Earth's surface. Aerial photography has been used for many years to survey large areas and provide such information for tasks such as geological mapping and cartography. Acquisition of imagery of portions of the Earth's surface from much higher altitudes than those customarily used for aerial photography offers significant advantages. Imagery from orbital altitudes allows a much greater ground area to be covered by a single image thereby essentially eliminating the need for mosaicking and resulting degradations in the composite image. A corollary result of the coverage achievable from satellite altitudes is that the variables of time and Sun angle are automatically held constant for large areas whereas with low-altitude aerial photography such constancy is difficult to achieve for large areas. In addition, the proper choice of satellite orbital parameters can provide repetitive coverage at essentially no additional cost.

A considerable number of tasks have been suggested for which the acquisition of satellite-obtained information would be useful. NASA has designated its program to investigate the applicability of satellite-obtained information to such tasks and the feasibility of obtaining such information as the Earth Resources program. The progress of the program has been such that the design of a spacecraft to demonstrate the technology required is now in progress. The tasks included in the Earth Resources program are grouped into discipline areas which include Geology, Hydrology, Geography, Oceanography, and Agriculture and Forestry. Other government organizations, primarily USDI, USDA, and NAVOCEANO are cooperating with NASA in the areas of their particular interest.

In this paper we term the tasks which have been proposed for accomplishment with the assistance of satellite-obtained information the objectives of the Earth Resources program, or of a particular satellite mission, as the case may be. The purpose of this paper is to present a summary of the objectives which have been suggested for the Earth Resources program and to provide detailed descriptions of the types of data which will be required to accomplish the objectives. Such information as has been published on this subject is scattered among many sources. Sources consulted during preparation of this summary include NASA contractor reports, reports of other government agencies and their contractors, journal and symposia articles, representatives of some of the major cooperating agencies, and contacts with some of the principal investigators associated with the program.

An extensive effort has been made to identify the sources of the information presented herein. In particular, the numerical values of the various data parameters have been referenced so that the original sources may be examined for arguments concerning the choice of particular values. It is hoped that this identification of sources will help to alleviate any problems caused by assignment of data parameter values in this report to objectives which may be somewhat different in intent from those with which they were associated in the original material.

Although most, if not all, of the objectives described herein have world-wide applicability, the description of area to be observed has been limited to those located in the United States including Alaska and Hawaii and, for the oceanography objectives, the portions of the Atlantic and Pacific oceans north of the equator. This restriction was made in the interest of economy of time and effort and does not imply that the performance of the various tasks for other parts of the world would not be useful.

This document thus provides a single source of information on objectives and their data requirements which may be used in a variety of ways in studies relating to Earth Resource missions. For example, the information in this document has been used in a study of orbit selection considerations for Earth Resources observations* and for a study of an early operational satellite system intended to satisfy as many objectives as possible with a single orbit-payload combination.**

The following section describes the methods used in selecting and defining the objectives and measurement requirements, after which the objectives are discussed in general terms by discipline area. The final section presents tabular summaries of the detailed measurement requirements. The appendix contains individual descriptions of each of the objectives and its measurement requirements.

SELECTION AND DEFINITION OF OBJECTIVES

From the sources mentioned above, the list of objectives shown in Table I was obtained. It was found that the objectives varied widely in both feasibility and the degree of definition of their data requirements. It thus became necessary to select a smaller group of objectives which are denoted by asterisks in Table I. The objectives in this group were selected on the basis that there was sufficient information available to provide a reasonable definition of their data requirements and that there was some evidence in the literature to indicate that acquisition of the necessary data from a spacecraft platform would be feasible. The possible

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* B. L. Swenson, "Orbit Selection Considerations for Earth Resources Observations", MAD Working Paper MS-68-18, December 31, 1968

** A. J. Stratton, "Earth Resources Satellite Capability Study", MAD Working Paper MS 70-2 benefits which might accrue from the accomplishment of the objectives is another factor which might be considered for selection of objectives. The benefits factor was not considered here since the estimates vary considerably with different sources. It was felt to be the better course of action to include all those objectives which were well-defined and probably feasible, leaving further selection on the basis of benefits as a future option.

For each of the selected objectives, all the values which could be found in the available information sources were listed for each measurement parameter. If multiple values were found for a particular parameter, a single nominal value or range of values was chosen and if no values were found, a value was estimated. The result is the set of "Objective and Measurement Descriptions" contained in the Appendix.

GENERAL DISCUSSION OF OBJECTIVES AND REQUIREMENTS

This section describes in general terms the types of tasks included as objectives in the various discipline areas and summarizes the major features of the measurement requirements for each of the disciplines. The discussions below illustrate the fact that the requirements for different objectives within the same discipline tend to be quite similar in most cases, whereas the requirements may be quite different for objectives in different disciplines.

Oceanography

The objectives in oceanography include iceberg detection and surveillance, determination of sea state, mapping of ocean currents, mapping of coastal areas, location of fish, and collection and relay of oceanographic data gathered by buoys. The latter objective would utilize a satellite simply to relay data rather than as a platform for remote sensing as would the other objectives. The concept of relaying data from sensors on the surface via a satellite link is embodied in the IRLS system being tested on the Nimbus B2 flight.

The oceanography objectives have perhaps the largest variety of requirements of any discipline. The sensors which could be used include passive microwave imagers, thermal IR scanning devices, radar scatterometers, radar imagers, and visual-near IR color or multispectral imagery (including metric quality imagery for coastal mapping). The single sensor which would be the most useful for the oceanography objectives considered here is a thermal IR scanner with $1.0^{\circ}C$ thermal resolution. At 90 m ground resolution it would provide data useful for three objectives and at 300 m resolution for two objectives. Although none of the information sources so indicated, it is felt that ground resolution worse than 300 m, say 1 or 2 km, would be still useful for current mapping, fish location, and similar tasks. The thermal IR scanner would not provide data when fog or cloud cover was present, as would be possible with longer wavelength systems.

The frequency with which observations should be repeated reflects the small time constant for variations in the ocean environment as compared to variations in the terrestrial environment. The frequencies of observation range from once per 6 hours to once per two days except for the coastal mapping objective which requires observations only twice per quarter, once at high and once at low tide.

Geology

The geological objectives include production of basic small-scale geologic maps at two scales ($1:10^6$ and 1:250,000) in order to complete and up-date existing map series, the discovery of new oil, mineral, and geothermal resources, and reconnaissance of geologically active areas. The sensing techniques with greatest applicability for geology are visual, radar, and thermal IR imaging. The most useful technique is visual imaging, with metric quality desired for the geologic mapping objectives. Ground resolution requirements range from 6 to 30 m desired and 30 to 120 m acceptable. The most stringent resolution requirement comes from the 1:250,000 mapping objective.

Radar imaging has considerable potential for geologic applications as it tends to emphasize important topographic and geologic features while suppressing effects of some non-geologic features. Ground resolution element requirements are similar to or slightly greater than those for visual imaging. Thermal IR imaging is useful for applications requiring information on the ground surface temperature distribution. The desired ground resolution is similar to that for radar imaging but ground resolutions of up to 300 m or even 3 km for volcano reconnaissance are considered acceptable.

The frequency of observation requirements for the various geologic objectives are quite similar to each other, and in fact, for many objectives they are the same. Since geologic conditions are essentially static on any time scale considered in the normal course of events, the requirement is basically to obtain complete coverage of the areas of interest once. The time of year is generally selected as summer or autumn so that snow cover will be minimal, and there is some preference for the autumn end of this time period as native vegetation correlates in some instances with geologic composition of areas and identification of some vegetation types is facilitated by the presence of autumn coloration. Also, the detection of surface features may be easier in some areas when deciduous forests have lost their leaves.

Sun angle plays an important role in the specification of visual imagery for geological applications. Low Sun angles increase the visibility of minor topographic features because of shadowing[62], whereas high Sun angles are desirable for high-quality color photography from which compositional variations may be inferred. Accordingly, two Sun-angle ranges have been specified for the geology objectives, $20\text{-}40^{\circ}$ and $60\text{-}90^{\circ}$.

Hydrology

The hydrology objectives include observation of snow cover in watershed areas to assist in prediction of stream-flow rates, monitoring of river and lake ice in the Great Lakes-St. Lawrence area as an aid to navigation and flooding due to temporary ice-jams, location of previously unknown areas of ground-water discharge, and the collection and relay of hydrological data gathered by in-situ measurement stations. The latter objective is similar to the oceanographic data collection objective except that the hydrological measurement stations have fixed locations, whereas oceanographic buoys may be of drifting type.

Visual imaging, either color or black and white, is desired for snow cover surveys, with the addition of thermal IR imaging being useful to help distinguish snow from clouds. The ground resolution requirements are 15 to 90 m for visual imagery and 900 m for IR imagery. The monitoring of ice and detection of ground-water discharges are best accomplished by detection of thermal variations. For the ice monitoring, a passive microwave imager or radar imager is recommended due to their cloud penetration capabilities, although it is unlikely that passive microwave systems will be able to achieve the required ground resolution of 15-90 m. Thermal IR or visual imagery are also applicable to this objective although cloud interference may create problems. The primary sensing technique for detecting ground water discharge is thermal IR imagery, with a resolution requirement of 30-90 m.

The required frequency of observation is fairly high for ice monitoring at once per week. Snow cover survey calls for observations once per two weeks with the capability for daily coverage at certain times being desirable. As the time variability of ground-water discharge is much less than that of the phenomena just mentioned, the frequency of observation for this application is much less, being twice per season or once per 6 weeks on the average. Once observations have been completed through a cycle of seasons, the observations presumably would need not be repeated for some time.

Agriculture and Forestry

The agriculture and forestry discipline is subdivided into the areas of crops, rangelands, and forests. In each of these areas, the objectives call for inventory of the resources present and for forecasting the expected yield. In addition, there is an objective concerned with detection of forest fires. With the exception of this last objective, the primary sensing technique is visual (multispectral) imaging in from three to five spectral bands with desired ground resolution ranging from 1.5-15 m and acceptable resolution from 30-120 m. For forest fire detection, the primary sensing technique is thermal IR imaging with a ground resolution of 18-100 m.

The frequency and time of observation requirements for crop inventory and forecast have been described in considerable detail in Addendum A of Reference 1 from which the requirements stated here have been adopted. The basic frequency cycle is once per two weeks. The frequency of observation for forest mapping has been set at once per week in order to utilize autumn coloration as an aid in species identification. As autumn coloration is a rather variable function of location and time, the relatively high frequency is required to give good coverage of the phenomenon. For timber inventory, the major requirement is for high resolution and observation frequency and coverage requirement calls only for a single sample coverage of 10% or more during late summer. Forest fire detection requires daily observations during periods of high fire danger and rangeland inventory calls for observations every one or two weeks depending on location and time of year.

The Sun angle requirement for the objectives requiring visual imagery is 60-90° to provide for the most accurate recording of color variations.

Geography

The geography objectives are concerned with providing accurate maps of the Earth's surface at a number of scales and with providing repetitive coverage of the more dynamic areas, including urban areas in particular, which will provide quantitative data on the pattern and intensity of changes in land use, industrialization, population density, and other geographic parameters. The primary sensor for most applications is visual imagery, either color photography or multispectral. The required ground resolution varies considerably depending on the particular application at hand. Small scale mapping ($1:10^6$) has the least stringent requirement at 50 m. The resolution requirement becomes tighter as the map scale becomes larger, and for some applications in urban areas, resolutions as small as one meter are desired.

Frequencies of observation for the general mapping objectives are once per quarter or once per 6 months, with up-dating thereafter at intervals from 6 months to as much as five years. For observations of the urban environment, no frequency requirements have been given due to the large variety of tasks which might be included as part of such an objective, with varying requirements for observations. A maximum observation frequency of once per month can safely be assumed, however.

Disaster Assessment

The objectives grouped under the category of disaster assessment provide for determining the effects on stricken areas of severe storms and other natural disasters. Visual and radar imagery rate the highest among the sensor systems for this application. Radar offers the particular advantage of being able to penetrate clouds, and to some extent rain, if appropriately designed. Such penetration might well be required for storm and flood damage where cloudy and rainy conditions might well prevail. The resolution requirements range from 3 m desired to 90 m acceptable.

The frequency of observation requirement for all objectives in this category is at least once per day. Even more frequent observations might well be desired. Observations would, of course, only be required at and immediately after the time of occurrence of such a disasterous event.

DETAILED SUMMARIES OF MEASUREMENT REQUIREMENTS

The detailed measurement requirements for the various objectives have been summarized in Tables II through VIII. Tables II through VII list the requirements which are pertinent to the selection or design of sensor systems including visual (Table II), thermal IR (Table III), radar (Table IV), and passive microwave (Table V) imaging systems, microwave radiometry systems (Table VI) and radar scatterometry (Table VII) systems. The requirements pertinent to the selection of orbits are listed in Table VIII.

In the case of objectives for which different types of visual imaging systems were specified under the three categories of sensing techniques (primary, supplementary, and alternate), only the most important type of imaging system was entered in Table II.

TABLE I

SUGGESTED EARTH RESOURCES TASKS

Oceanography

*Iceberg Detection and Surveillance
*Sea State
*Ocean Current Mapping
*Map Coastal Areas
*Locate Fish
*Buoy-Satellite Data Collection and Relay
Sea Ice
Harbor Ice Build-up and Break-up
Shore Erosion and Build-up
Coastal Currents
Air/Sea Interaction and Cloud Patterns
Sea Surface Height & Shape
Map Topography of Atolls, Shoals, Reefs, etc.
Detect Coastal Heavy Mineral Concentrations
Locate Undersea Oil Deposits
Locate Undersea Mineral Deposits
Study Kelp and Seaweed Beds

Geology

*Geologic Mapping at $1:10^6$
*Geologic Mapping at 1:250,000
*Locate Mineral Deposits
*Oil Exploration
*Earthquake Belt Reconnaissance
*Geothermal Power Sources
*Volcanic Belt Reconnaissance
Volcanic Eruption Warning System
Earthquake Warning System
Crustal-Mantle Studies
Location of Surface Mines and Dumps

TABLE I (cont.)

Radiant Temperature Mapping

Topographic Mapping

Composition of Surface Materials

Erosion and Sedimentation

Detect Potential Landslides

Monitor Sand Dune Movements

Observe Evolution of Arid Region Topography

Impact Crater Survey

Polar Region Studies

Glacial Studies

<u>Hydrology</u>

*Snow Cover Survey

*Monitor River & Lake Ice

*Locate Areas of Ground-Water Discharge

*Data Relay From Network of Hydrological Stations

Mapping of Drainage Basins

Survey Soil Moisture Distributions

Monitor Lake & Stream Surface Temperatures

Monitor Evaporation & Transpiration Water Losses

Detect Presence & Movement of Pollutants

Measure Variation in Lake & River Water Levels

Survey Erosion & Sedimentation Patterns

Determine Changes in Stream Banks & Channels

<u>Agriculture & Forestry</u>

*Major Crop Inventory & Forecast

*Forest Mapping

*Timber Inventory

*Forest Fire Detection

*Rangeland Mapping & Assessment of Forage Potential

TABLE I (cont.)

Soil Mapping

Determine Migration Patterns of Animals, Pests & Insects

Discover Potentially Usable Land Areas

Discover Ecological Relationships

Catalog Soil Fertility and Envirionmental Characteristics

Detect & Assess Infestation Damage, Disease, etc.

Determine Energy Balance in Forest Lands

Determine Total Terrestrial Biornas

Wildlife & Recreation Management

Improve Knowledge of Vegetation Distribution

Improve Knowledge of Animal Distribution

Detect Dynamic Biological Populations

Detect & Monitor Migration Patterns

Track & Count Migratory Birds & Wildlife

Assessment of Wildlife and Fisheries Habitat

Geography

*Small Scale Geographic Mapping

*Large Scale Regional Geographic Mapping

*Surveys of Urban Environment

Identify Transportation Facilities & Networks

Survey, Classify & Plan Industrial Facilities

Evaluate Dynamics of Urban Land Use

Survey Sites for Development of New Settlements

Monitor Regional Land Use Patterns

Inferring Population Distribution

Disaster

*Storm Damage Assessment

*Earthquake Damage Assessment

*Volcanic Eruption Damage Assessment

*Flood Damage Assessment

Improve SAR Operations

Provide Tidal Wave Warnings

* Tasks for which detailed measurement requirements were documented

TABLE II

VISUAL IMAGERY REQUIREMENTS

	Objective	Type of Imagery	Ground Res. (m) Desired	Ground Res. (m) Acceptable	Swath Width (km)	Comments
	OCN 4	C*	3	60	90	Metric Quality Desirable
	GLG 1	C	30	120	180	Metric Quality Desirable
	GLG 2	C	6	30	90	Metric Quality Desirable
	GLG 3	C	6	90	180	Metric Quality Desirable
	GLG 4	C	6	90	180	Metric Quality Desirable
	AGF 1	MS*-5 bands	15	60	45	Metric Quality Desirable Visual and Near IR
	AGF 2	MS-3 bands	15	120	180	Metric Quality Desirable Bands in Red, Green, Near IR
	AGF 3	MS-3 bands	1.5	30	180	Bands in Red, Green, Near IR
PRIMARY SENSOR	AGF 5	MS-3 bands	10	120	> 90	Bands in Red, Green, Near IR
	HYD 1	C or BW*	15	90	180	
	GEG 1	C	12.5	50	≥ 112	Metric Quality Desirable
	GEG 2	C	1.25	5	≥ 32	Metric Quality Stereo Imagery Desirable
	GEG 3	C	1	50	≥ 40	
	DIS 1	C	3	90	18	
	DIS 2	C	3	90	18	
	DIS 3	C	3	90	18	
	DIS 4	C or BW	6	15	45	
SUPPLEMENTARY SENSOR	OCN 5	C	6	300	90	
	GLG 6	C	30	180	90	
	HYD 3	C	3	6	45	
	OCN 2	C or BW	6	30	180	
	OCN 3	C	30	300	180	
ALTERNATE SENSOR	GLG 5	C or BW	120	300	180	
	GLG 7	C	30	120	180	
	HYD 2	C or BW	15	90	180	

*C = Color, MS = Multispectral, BW = Black and White

TABLE III

THERMAL INFRARED IMAGERY REQUIREMENTS

	Objective	Wavelength Band (μ)	Ground Res. (m) Desired	Ground Res. (m) Acceptable	Temp. Res. (°C)	Swath Width (km)
PRIMARY SENSOR	OCN 3	8-13	30	300	0.1-2.0	180
	OCN 5	8-13	30	300	0.5-1.5	90
	GLG 5	8-13	120	300	0.5-1.0	180
	GLG 7	3.4-4.2, 8-12	150	3000	1.0	180
	AGF 4	4.5-5.3	18	100	1.0	90
SUPPLEMENTARY SENSOR	HYD 3		30	90	0.5-1.0	45
	GLG 1		30	300	0.5	180
	GLG 2		15	150	0.5	90
	GLG 3	3.4-4.2, 8-12	30	300	0.5	180
	GLG 6	3.5-4.2, 8-12	150	300	0.5-1.0	90
	HYD 1			900	1.0	180
	DIS 1		3	90	1.0	18
	DIS 2		3	90	1.0	18
	DIS 3	4.5-5.3, 8-12	30	300	1.0	18
	OCN 1	8-13	20	90	1.0-2.0	180
	OCN 4	3-14	3	60	1.0	90
ALTERNATE SENSOR	GLG 3	3.4-4.2, 8-12	30	300	0.5	180
	HYD 2		15	90	0.5-1.0	180
	DIS 4		6	15	1.0	45

TABLE IV

RADAR IMAGERY REQUIREMENTS

	Objective	Frequency or Wavelength	Ground Res. (m)		Swath Width (km)
			Desired	Acceptable	
PRIMARY SENSOR	OCN 1	Microwave	5	90	180
	GLG 1		30	150	180
	GLG 2		15	60	90
	GLG 6		30	150	90
	HYD 2	Microwave	15	90	180
	DIS 1		3	90	18
	DIS 4		6	15	45
SUPPLEMENTARY SENSOR	GLG 3		30	90	180
	GLG 4		6	90	180
	GLG 7		30	150	180
	GEG 1		12.5	50	≥ 112
	GEG 2		1.25	5	≥ 32
	GEG 3		1	50	≥ 40
	DIS 2		3	90	18
	DIS 3		3	90	18
ALTERNATE SENSOR	OCN 2	0.5-3 cm	6	30	180
	OCN 4	1-30 cm	3	60	90
	OCN 5		6	300	90
	AGF 1	Multi-freq.*	?	?	
	AGF 3	?	?	?	

*Concept for future development

TABLE V

PASSIVE MICROWAVE IMAGERY REQUIREMENTS

	Objective	Wavelength Band (cm)	Ground Res. (m)		Temp. Res. (°C)	Swath Width (km)
			Desired	Acceptable		
PRIMARY SENSOR	OCN 1	3-30	5.	90	1.0-2.0	180
	OCN 3	3-30	30	300	0.1-2.0	180
	OCN 5	5	30	300	0.5-1.5	90
	HYD 2		15	90	0.5-1.0	180
ALTERNATE SENSOR	GLG 3		30	300	0.5	180
	AGF 4		18	100	1.0	90

TABLE VI

MICROWAVE RADIOMETRY REQUIREMENTS

Objective	Wavelength Band (cm)	Ground Res. (m)		Temp. Res. (°C)	Comments
		Desired	Acceptable		
OCN 2		1000	3000		Measures brightness temp. vs. angle of incidence
HYD 1					For determination of snow wetness factors

TABLE VII

RADAR SCATTEROMETRY REQUIREMENTS

Objective	Wavelength Band (cm)	Ground Res. (m)		Comments
		Desired	Acceptable	
OCN 2		1000	3000	Measures scattering cross-section vs angle of incidence

TABLE VIII

ORBIT RELATED REQUIREMENTS

Objective	Latitude Range(deg. N)	Sun Angle (deg.)	Time of Observation	Frequency of Observation	Swath Width(km)	Approximate Location
OCN 1	35-70	--	Feb.-July	Once per 2 days	180	Grand Banks
OCN 2	0-65	60-90 A*	All year	Once per 6 hrs.	180	Atlantic & Pacific
OCN 3	0-65	60-90 A	All year	Daily	180	Atlantic & Pacific
OCN 4	25-60	30-90 P*	All year	Quarterly	90	U.S. coasts
OCN 5	25-50	60-90 S*	June-Sept. for tuna	Daily	90	Pacific
GLG 1	30-70	60-90 P, 20-40 P	July-Oct., prefer Sept.-Oct.	Once at each Sun angle	180	Entire U.S., Alaska, Hawaii
GLG 2	30-70	60-90 P, 20-40 P	Late summer or autumn	Once at each Sun angle	90	Entire U.S., Alaska, Hawaii
GLG 3	30-70	60-90 P, 20-40 P	July-Oct., prefer Sept.-Oct.	Once at each Sun angle	180	West U.S., Alaska, Appalachians, Ozarks, Black Hills
GLG 4	30-70	60-90 P, 20-40 P	July-Oct., prefer Sept.-Oct.	Once at each Sun angle	180	U.S. except Rockies & Sierras
GLG 5	30-65	30-90 A	Summer	Once	180	Same as GLG 3
GLG 6	30-65	60-90 S, 20-40 S	July-Oct.	P once; S once at each Sun angle	90	West U.S., South Alaska, Aleutians
GLG 7	30-65	60-90 A, 20-40 A	July-Oct.	P once; A once at each Sun angle	180	Western U.S., Alaska
AGF 1A	37-46	60-90 P	Mar.15-Sept.10	Once per 2 wks.	45	Corn Belt
1B	27-32	60-90 P	May1-Oct.1	Once per 2 wks.	45	Miss.Delta-E. Texas
1C	34-48	60-90 P	Mar.20-Nov.1	Once per 2 wks.	45	Great Plains

TABLE VIII (cont)

Objective	Latitude Range(deg.N)	Sun Angle (deg.)	Time of Observation	Frequency of Observation	Swath Width(km)	Approximate Location
AGF 2	25-48	60-90 P	Mar.-May, Sept.-Nov.	Weekly	180	See Appendix
AGF 3	25-48	60-90 P	July-Aug.	Once(10% sample)	180	See Appendix
AGF 4	25-48	--	July-Oct.	Daily	90	See Appendix
AGF 5	25-48	60-90 P	March-Aug.	Weekly	90	See Appendix
HYD 1	35-48	30-60 P	Dec.1-June30	Once per 2 wks.	180	Pacific N.W., Rockies, Sierras
HYD 2	42-50	30-60 A	Nov.15-Jan.15, Mar.1-April30	Weekly	180	Great Lakes and St. Lawrence Seaway
HYD 3	30-48	Night P 60-90 S	All year	Twice per season	45	Areas in U.S.
GEG 1	25-70	30-60 P	All year	Once per season	≥ 112	Alaska highest priority
GEG 2	25-70	30-60 P	Summer preferred	Once per 6 mos.	≥ 32	Areas in U.S. & Alaska
GEG 3	25-70	60-90 P	Variable	Variable	≥ 40	Urban areas in U.S.
DIS 1	25-70	20-90 P	On demand	Daily	≥ 18	Variable
DIS 2	25-70	20-90 P	On demand	Daily	≥ 18	West U.S., So. Alaska, Aleutians
DIS 3	30-48	20-90 P	On demand	Daily	≥ 18	Variable
DIS 4	30-48	20-90 P	On demand	Daily	45	Along major rivers

*P means that visual imaging is a primary sensing technique,
S that it is supplementary, and
A that it is an alternate.

APPENDIX - OBJECTIVE AND MEASUREMENT DESCRIPTION SHEETS

This appendix contains the set of objectives and measurement descriptions which resulted from the study. Each objective is briefly described, the sensors useful for obtaining the necessary data are noted, and a list of values for the measurement parameters is given. The objectives are organized by disciplines in the following order: Oceanography, Geology, Hydrology, Agriculture and Forestry, Geography, and Disaster Assessment. A code notation has been used to facilitate listing of the objectives on figures or in tables. The code consists of three letters related to the title of the discipline area plus a number to indicate the individual objective within the discipline. The letter symbols are:

OCN - Oceanography
GLG - Geology
HYD - Hydrology
AGF - Agriculture and Forestry
GEG - Geography
DIS - Disaster Assessment

The various entries on the description sheets were defined as follows:

CODE: (OCN 1, GEG 2, etc., as described above)

OBJECTIVE: A brief descriptive title

DESCRIPTION: A few sentences outlining what is to be done and why.

METHOD: What information is needed and what phenomena are to be sensed.

PRIMARY SENSING TECHNIQUE: The single technique which can best provide the needed information. If two techniques are approximately equal in capability, both are listed.

SUPPLEMENTARY SENSING TECHNIQUES: Additional techniques which could be used to provide information supplementary or complementary to that provided by the primary sensor.

ALTERNATE SENSING TECHNIQUES: Additional techniques which give an alternate method of obtaining the information provided by either primary or supplementary techniques.

GROUND RESOLUTION: A linear dimension only is given as a specification for required ground resolution, as noted in each of the pertinent information sources. A complete and thorough specification would include additional factors such as contrast ratios, and the number of lines required within the resolution element. Such considerations are generally not to be found in the source material and they are not included here.

THERMAL RESOLUTION: The maximum allowable detectable temperature increment.

SUN ANGLE: Measured up from the horizontal to the Sun, thus, the Sun angle is a maximum at local noon.

SWATH WIDTH: The width of the area imaged on a single satellite pass.

LOCATION TO BE OBSERVED: The location of interest for the objective has been described either in words, or in most cases indicated on a map accompanying the objective description sheet.

OBSERVATION SCHEDULE: Describes the schedule of observations required to accomplish the objective, including the time of year, number of observations, and the frequency of repetition when multiple observations are required.

RESPONSE TIME: The maximum time between acquisition of the data and receipt of the resulting information by the user that is consistent with the purpose of the objective.

It will be noted that the values for the measurement parameters are arranged in two columns. The first column includes the values which have been found in the information sources. In a number of cases, the values from different sources are in disagreement. In these cases, one or two values have been placed in the second column under the heading "Recommended Values." Where two values have been written in the second column, the first represents the desired value for achievement of the objective and the second (in parentheses) is the worst value of the parameter consistent with achievement of the objective.

The fact that there is not complete agreement among the various sources on the values of particular parameters underlines the fact that in many cases the optimum value for the parameter has yet to be determined. Thus the fact that certain values have been recommended here for the parameters does not indicate that the values are necessarily accurately known. The recommended values represent only estimates of what the parameters should be.

The descriptions are arranged according to the following index listing:

Geography

GEG 1 Small Scale Geographic Mapping - Scale >1:250,000
GEG 2 Large Scale Regional Geographic Mapping - Scale <1:250,000
GEG 3 Urban Environment

Disaster Assessment

DIS 1 Storm Damage Assessment
DIS 2 Earthquake Damage Assessment
DIS 3 Volcanic Eruption Damage Assessment
DIS 4 Flood Damage Assessment

CODE: OCN 1

OBJECTIVE: Iceberg Detection and Surveillance[4, 1]

DESCRIPTION: To keep ships informed on the location of icebergs.[6] Iceberg movements can also be used as tracers in studying ocean currents.[13] Their presence or absence can also be of use in determing the salinity of the surface water.[13]

METHOD: Frequent, periodic observations will be required for accurate location of icebergs. An all weather capability would be very desirable since inclement weather is encountered much of the time.[14]

With passive microwave imaging, the brightness temperature difference between ice and water is very large (60-120°K) although both may be very near the same physical temperature.[4] Microwave would also be useful day or night and would penetrate both fog and cloud cover.[4]

PRIMARY SENSING TECHNIQUES: Passive Microwave Imaging,[4,6] 3-30 cm.
Microwave Radar[1], 3-30 cm.[6]

ALTERNATIVE SENSING TECHNIQUE: Infrared Imaging[4], 8-13 μ[6]

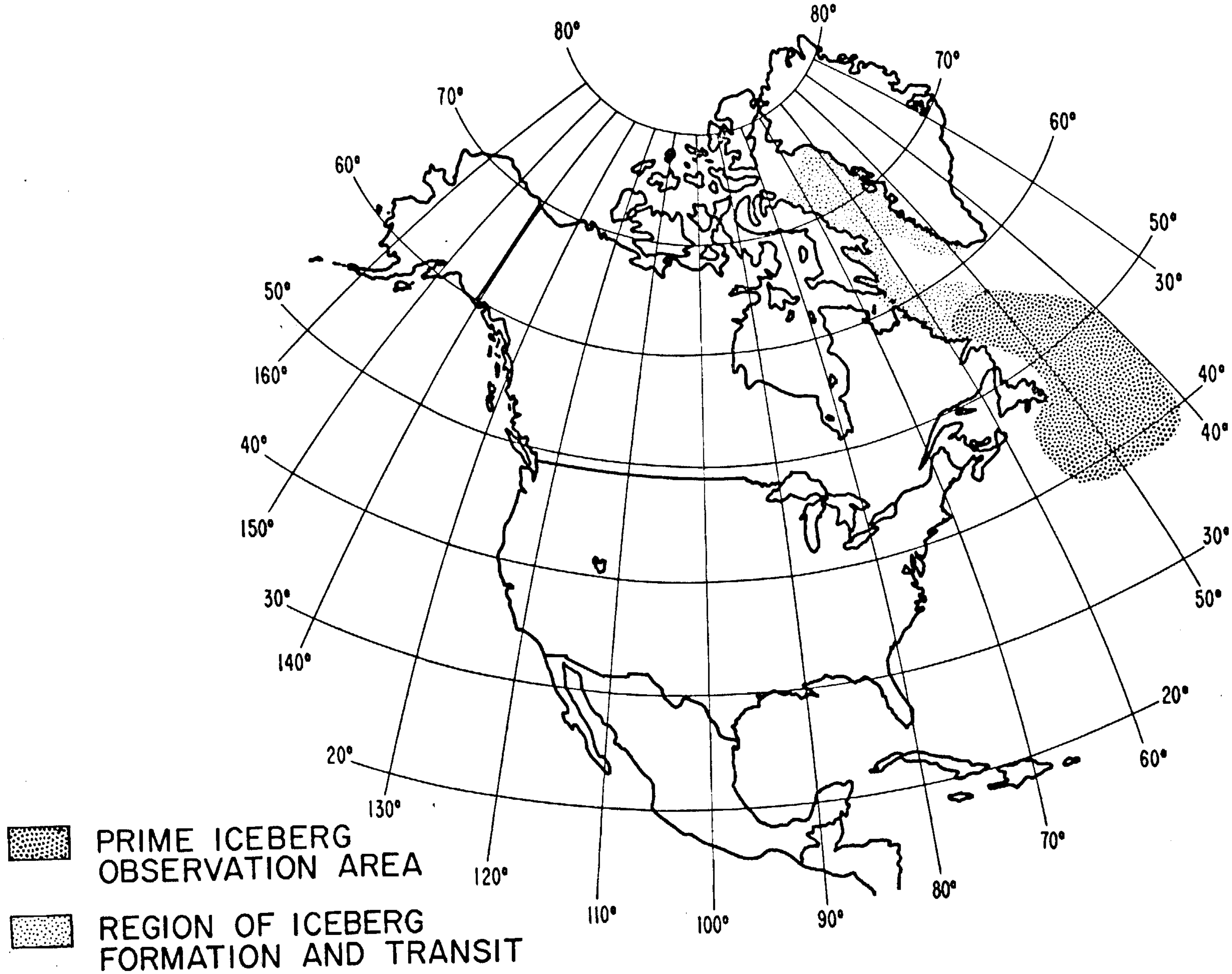
MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Microwave Imaging	1.5-3m[1] 20m[6] 10m[30] 5m[31]	5m (90[1])
Radar	60m[1] 20m[6] 10m[30] 5m[31]	5m (90[1])
IR	20m[6]	20m[6] (90[1])
THERMAL RESOLUTION:	1.0-2.0°C[6]	
SWATH WIDTH:	180 km[1]	

LOCATION TO BE OBSERVED: See map

OBSERVATION SCHEDULE: Late February through early July.[14] Observations should be made at least every 48 hours.[1] Coast Guard sends out iceberg reports twice a day.[14] — Once per 2 days

RESPONSE TIME: Less than 6 hours.[1]

OCN I ICEBERG DETECTION AND SURVEILLANCE



CODE: OCN 2

OBJECTIVE: Sea State

DESCRIPTION: Increase efficiency of shipping by selecting routes with the most favorable weather conditions for ocean crossing.[1,6] Assist weather forecasting by studying air/sea interactions.[4] Knowledge of sea state would also be of value to commercial fishermen.[4] Monitor effect of ocean storms on coastal area; track and warn of tidal waves.[5]

METHOD: Radiometry and radar have advantages of not being constrained by cloud cover or night.[4,38] Radar wavelengths of less than 3 cm are seriously attenuated by clouds and storms.[6] With microwave radiometry correlate brightness temp. with roughness.[4,38] Visual region involves observation of glitter and non-glitter areas--brightness of glint related to roughness.[4,6,13]

PRIMARY SENSING TECHNIQUE: Radar scatterometer.[1,6,30,4], 10-70 cm[6]
Microwave radiometer[4,6,38]

ALTERNATE SENSING TECHNIQUE: Radar Imaging,[1,4,6] 0.5-3 cm[6]
Visual Imaging[1*]
Data Collection System[3,6,38]
Radar or laser altimeter

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Radar Scatterometer	1500-3000m[1] 20-100m[6] 1.5 km[3] 1 km[30]	1 km (3 km)
Optical	6-30m[1] 3-30m[3] 300-1500m[3] 30-300m[3]	6m (30m[1])

*See OCN 6

SUN ANGLE·		60-90°
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	Minimum - N. Atlantic Shipping Routes Desired - All oceans 0-65° N. Lat.	
OBSERVATION SCHEDULE:	2-6 hrs[1] 2 per day[30]	Every 6 hrs
RESPONSE TIME:	1 - 2 hrs[1]	

CODE: OCN 3

OBJECTIVE: Ocean Current Mapping

DESCRIPTION: Periodic ocean current maps would be useful for increasing efficiency of ocean shipping[6,34], assisting weather forecasting[4,6], and assisting commercial fishermen in fish location[1,6].

METHOD: Prepare frequent thermal maps of the sea surface[4,6]. Since many of the sea's characteristics are dynamic and hence, time dependent, repeated periodic coverage is much more valuable than a single profile map[6].

PRIMARY SENSING TECHNIQUES: IR Imaging[30,4,3] 8-13[6], 10 μ[6]
Passive Microwave Imaging[30] 3-30 cm
5 cm[30]

ALTERNATE SENSING TECHNIQUE: Visual (color) imaging[4,1,6,3]
Multispectral photography[6]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Thermal IR Imaging	100m[30] 65-320m[3] 30-300m[6]	30m (300m)
Passive Microwave Imaging	100m[30] 30-300m[6]	30m (300m)
Visual Imaging	65-320m[3] 20m[6] 30m[6] 100m[30]	30m (300m)
THERMAL RESOLUTION:	0.2-0.5°C[36] 0.1°C[30] 0.1-2.0°C[6]	0.1°C (2.0°C)
VELOCITY RESOLUTION:	1 cm/sec[30]	
SUN ANGLE:	45-55°[1]	60-90°

SWATH WIDTH: 180 km

LOCATION TO BE OBSERVED: North Atlantic and North Pacific Oceans, 0-65° N. Lat.

OBSERVATION SCHEDULE: 3 per week[30]. Daily 36 Daily

RESPONSE TIME: 6 hours

CODE: OCN 4

OBJECTIVE: Map Coastal Areas

DESCRIPTION: Prepare accurate coastline maps and nautical charts[4,6,42] improve accuracy of present charts[4,6,42], aid ship navigation along coasts by locating shoals, reefs, sand bars[4,6] etc. and monitoring seasonal and storm induced changes in such coastal structures[3,6]. Provide accurate maps for planning and development of coastal areas[1].

METHOD: Using visual (color) imaging, areas of equal blue intensity indicate areas of equal depth[4]. Under conditions of favorable visibility depths down to 300' or more can be observed[39]. The spectral region of maximum transparency in water is 400-600 μ [35]. Construction of iso-density prints assists in determing depth contours[4]. Observations should be made periodically and at least once at high and once at low tide to obtain tidal contrast.

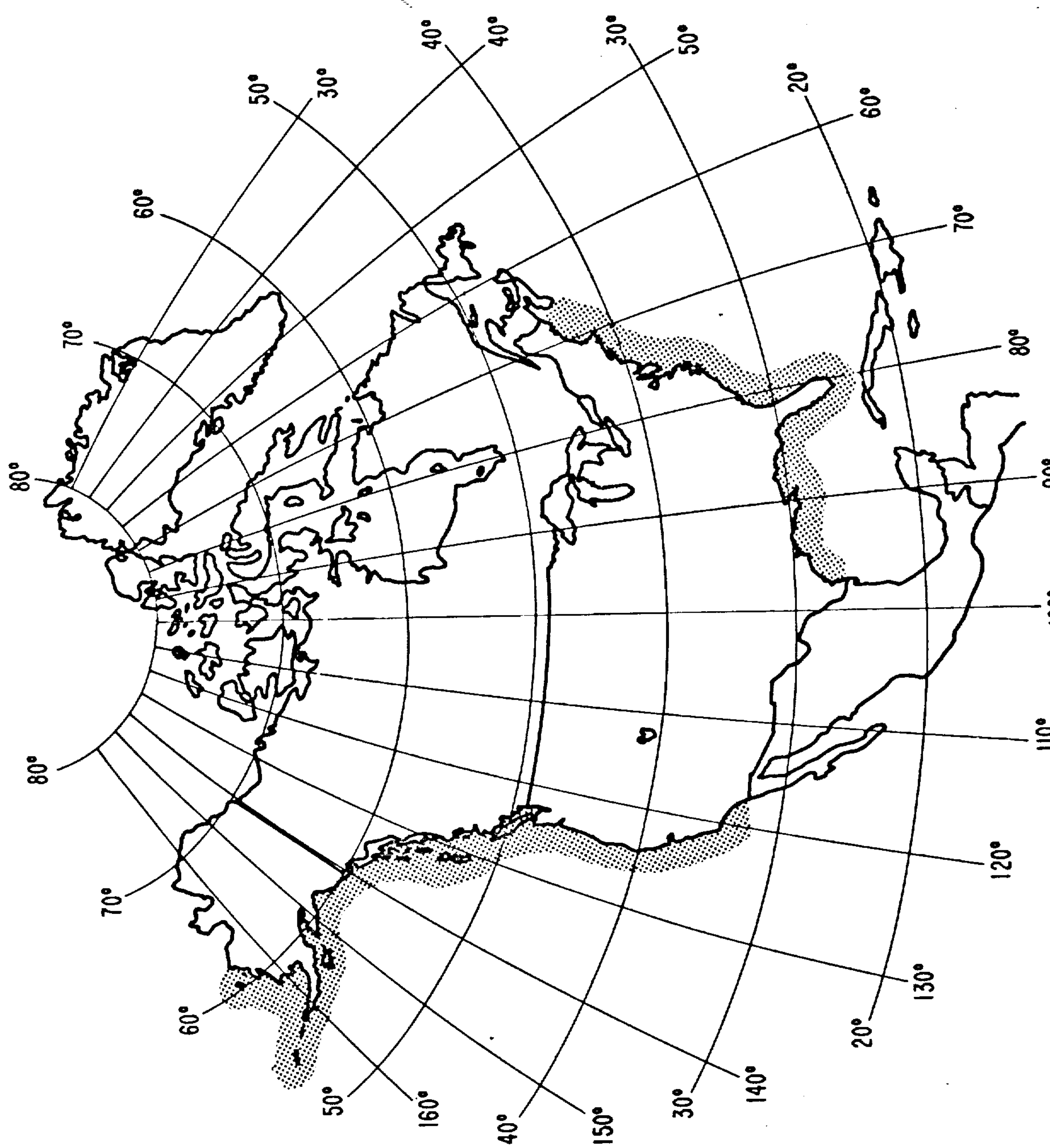
PRIMARY SENSING TECHNIQUE: Visual (Color) Imaging[1,4,6,30,42] (metric quality desirable)[6]
Multi-spectral Imaging[4,6,30]

ALTERNATE SENSING TECHNIQUES: Radar imaging[6,30] 1-30cm[6]
1-10cm[6]
IR imaging[3] 3-14μ[3]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Visual (Color) Imaging	20m[6] 1m[30] 3-30m[1,3] 60m[1] 3-18m[1]	3m (60m)
Thermal IR Imaging	0,3-3m[3]	3m (60m[1])
Radar Imaging	20m[6]	3m (60m[1])
THERMAL RESOLUTION:		$1.0^{\circ}C$
DEPTH RESOLUTION:	0.3-3m[37]	
SUN ANGLE:	$30-90^{\circ}$ [1] $60-90^{\circ}$ [1]	$30-90^{\circ}$

SWATH WIDTH:	90km[1]	
LOCATION TO BE OBSERVED:	See Map	
OBSERVATION SCHEDULE:	1 per month[30] 1 per year[30] at least twice[1] monthly[1]	quarterly, at high and low tides
RESPONSE TIME:	one week[1]	

OCN 4 MAP COASTAL AREAS



CODE: OCN 5

OBJECTIVE: Locate Fish

DESCRIPTION: To aid commercial fishermen in locating schools of fish. 85-90% of commercial fishermen's time is spent in search of fish[6]. New fishing grounds possibly may be located[6]. Also would be helpful in studying migration of fish schools[4,5].

METHOD: Probably the most immediately productive approach spacecraft would be locating areas (via thermal mapping) where the ocean's surface temperature is favorable for a given species of fish[4,6,41]. Location of current boundaries and areas of upwelling should also be productive.[3,6,41] Direct visual imaging of fish schools may be possible [4] - especially through spotting the effects of shadowing (color contrasts), surface disturbances and fish trails.[1] Locating turbid waters and currents along coasts via color imaging would aid shrimp fishermen.[4] Since cloud cover is common over the oceans, radar and microwave imaging would provide an all weather, 24 hour capability - radar images have already been used to detect current boundaries and kelp beds.[4]

IR imaging can be useful in detecting chlorophyll, bioluminescence, algae, oil, etc.[4], as well as temperature. All matter containing chlorophyll shows up vividly in pink when imaged in IR color film.[4] Since ocean areas rich in algae are probably enriched in fish food, these areas should be more productive for fishermen. Since fish oils have unique spectra in the IR and UV, spectroscopy may also be utilized from space eventually.[4,6] (The Barringer IR absorption spectrometer[1,4] is under development.) Multi-spectral imaging techniques should include 4 bands in the visible, 2 in the near IR and one thermal band.[5]

PRIMARY SENSING TECHNIQUES: IR imaging[4,6,30] 8-13μ
Passive Microwave imaging[6,30], 5 cm[30]

SUPPLEMENTARY SENSING TECHNIQUE: Color IR photography[4]
Visual (color) imaging[1,4]

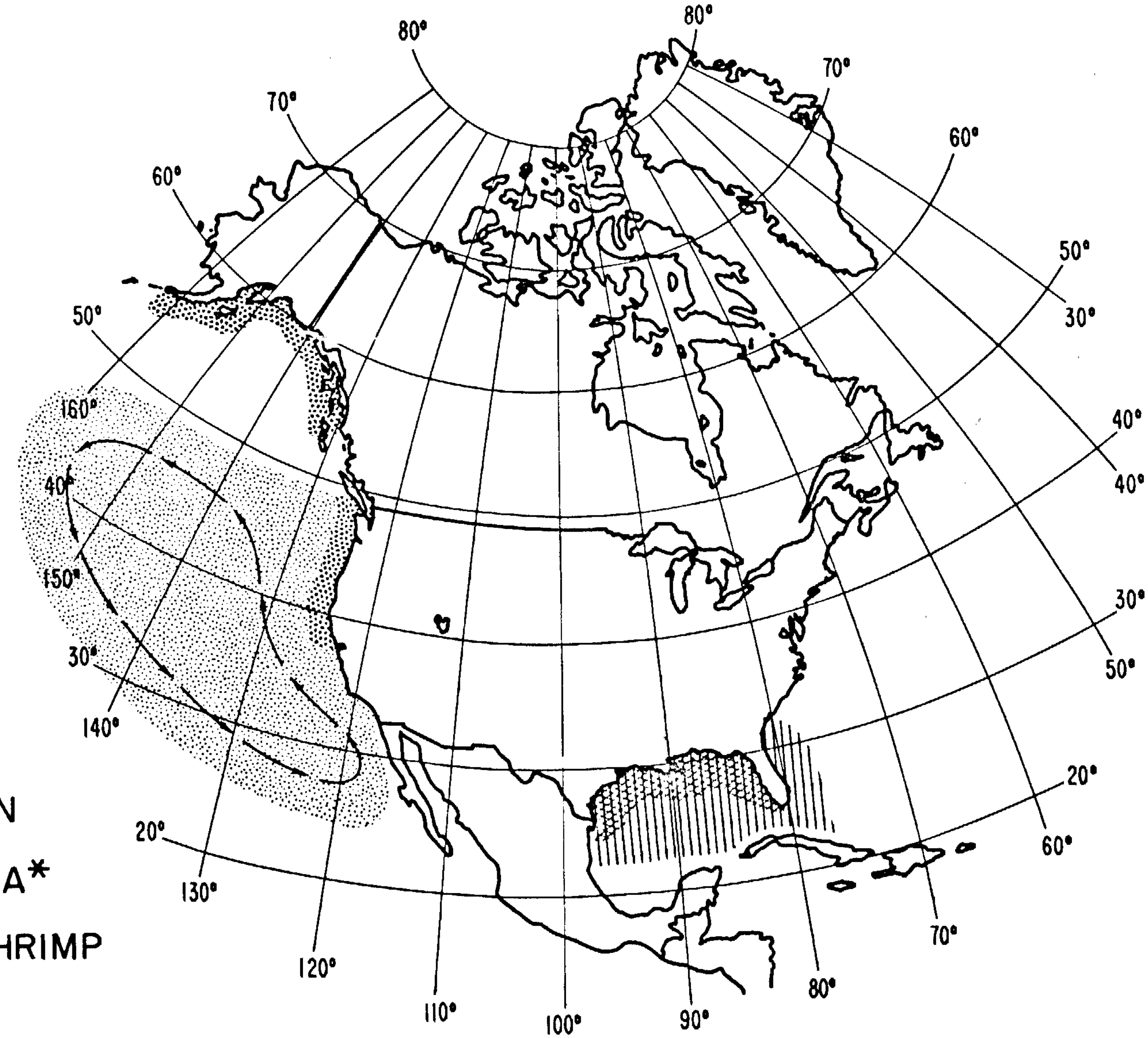
ALTERNATE SENSING TECHNIQUES: Multi-Spectral Imaging[3,6,30,5]
*Buoy-Satellite Data Collection System[1,5]
Radar Imaging[4]
IR Absorption Spectrometry[1,4]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Thermal IR imaging	30m[6,30] 150-1500m[3] 15-300m[3]	30m (300m)
Visual and Near-IR Imaging	50m[30], 30m[6]	6m (30m) for fish schools

	6-15m[1] 1.8-30m[3] 15-300m[3] 150-1500m[3]	30 (300m) for currents
Passive Microwave Imaging	30m[6,30]	30m (300m)
THERMAL RESOLUTION:	1-0°C[5] 0.5°C[30] 0.3°C[1] 0.5-1.5°C[6]	0.5°C (1.5°CO)
SUN ANGLE:	60-90°[1] 45-55°[1]	60-90°
SWATH WIDTH:	90 km[1]	
LOCATION TO BE OBSERVED:	See map	
OBSERVATION SCHEDULE:	4 per day[30] daily[1] every 2 hours	Daily
	Albacore: June-Sept.[5] Menhaden: April-Oct.[3]	
RESPONSE TIME:	6 hours[1] 1-2 hours[1]	6 hours

*The buoy-satellite technique outlines in OCN 6 could also be used for this objective. Not only could the buoy sensors provide information on whether the local temperature, salinity etc. was favorable for the presence of given fish species, but also fish could be tagged accoustically (as outlined in ref. 5, p. 155) with tags that would respond to the signal from a buoy. The tag would act like a transponder and emit sound only when interogated.[5]

OCN 5 LOCATE FISH



PACIFIC SALMON

ALBACORE TUNA*

GULF COAST SHRIMP

MENHADEN

(*ARROWS INDICATE MIGRATION DIRECTION, SEE REF 5)

CODE: OCN 6

OBJECTIVE: Buoy-Satellite Data Collection and Relay[1,4,32]

DESCRIPTION: To monitor daily and seasonal variations in sea state and local weather. Buoys would collect data on surface, atmospheric and oceanographic parameters.[32] An oceanic buoy system would aid in weather forecasting, fish location[1], and ship routing.[31] Other potential beneficiaries might include agriculture, offshore oil and gas, construction, shore recreation and pollution.[32] It is also important to build up a bank of ground truth data for correlation with satellite (and/or aircraft) images.[33]

METHOD: Plant a system of buoys throughout the oceans, each with an array of sensors to continuously monitor selected oceanographic and atmospheric parameters in its vicinity and relay the data via satellite.

Travelers Research Corp. has recently completed a "Study of the Feasibility of National Data Buoy Systems"[32] and has postulated two different buoy systems--one costing $\$\frac{1}{2}$ billion and the other \$1 billion over a ten year period. The $\$\frac{1}{2}$ billion system (a network of buoys restricted to the Northern Hemisphere in water between 0 and 60° N. Lat.) envisions 150 buoys along coastal North America with 180 km grid spacing. An additional 100 buoys in lakes and estuaries and 50 buoys for research purposes would make a total of 590 buoys in the system.

The \$1 billion system (a worldwide network with buoys located between 60° N. Lat. and 60° S. Lat.) would include 400 buoys in deep oceans, 585 along coastal North America, 200 in lakes and estuaries, and 115 for research, making a total of 1300 buoys in the total system. Each buoy would monitor up to 69 different parameters (such as water and air temperature, salinity, current speed and direction, wind speed and direction, wave dimensions etc.). Sensors would be located both on the buoys and along mooring lines down to depths of 5000 meters.

An on-board computer would sequentially interrogate the sensors, process and store the data. The buoy would then transmit the stored message. It is planned that agencies and/or users should have the data available within an hour of interrogation time. According to TRC, such a buoy system would be very cost effective with yearly economic benefits of the order of 10^8 - 10^9 \$/yr.

MEASUREMENT PARAMETERS:

GROUND RESOLUTION: Buoys placed as close as 180 km[32]

LOCATION TO BE OBSERVED: Ocean areas between 0 and 60° N. Lat. or between 60° S. Lat. and 60° N. Lat.

		RECOMMENDED VALUES
INTERROGATION FREQUENCY:	3-6 hours[32] twice a day[4] 2 hours[1]	2 hours
RESPONSE TIME:	1-2 hours[1] 1 hour[32]	1 hour

CODE: GLG 1

OBJECTIVE: Geologic Mapping 1:1,000,000

DESCRIPTION: Geologic maps are basic planning and study documents.[1] Accurate maps obtained from satellite photography would be useful in many areas such as location of oil and minerals, water management, and natural resource studies.[12,1] Satellite mapping would be important for remote areas (especially Alaska).[12] Many areas have still not been mapped and others only poorly or inaccurately. Gemini photos demonstrate the desirability and practicality of space mapping.[50,46] Many structures not recognized in field studies have been found.[46,50] The patchwork appearance of aircraft photomosaics makes them difficult to use for geologic interpretation.

METHOD: Geologic maps prepared from satellite photos would be helpful in recognizing major structure, lineaments, lithologic units and large subtle anomalies.[50.1.46] Orthophotographic maps would provide important base data for regional exploration and resource data.[12] Color photographs excell in information capacity, simplicity and reliability.[3] Radar shows topography clearly, offers all weather capability and the possibility of penetrating below the surface.[3,49] Radar images allow interpretation of regional geomorphic and geologic features with a high degree of success.[9] Radar suppresses distracting and redundant detail.[48]

PRIMARY SENSING TECHNIQUE: Visual (color) imaging[3,46,1] (metric quality desirable)[1]
Radar imaging[9,48,3]

SUPPLEMENTARY SENSING TECHNIQUE: IR imaging[47,3]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Visual Imaging	30m[1] 300-3000m[3] 100m[11] 450m[11]	30m (120m[1])
Radar Imaging	3-30m[3] 15-150m[3] 300-3000m[3] 100-450m[11]	30m (150m)
IR Imaging	3-300m[3] 300-3000m[3] 100-450m[11]	30m (300m)
GROUND RESOLUTION:	$0.5^{\circ}C$[1]	
SUN ANGLE:	30-60°	20-40°

	Coverage at 2 angles desirable[1]	and $60-90^{\circ}$
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	Entire USA, Alaska and Hawaii	
OBSERVATION SCHEDULE:	Once (at each Sun angle)[1]. Coverage desirable during autumn.[1,3]	July-Oct. preferable, especially Sept.-Oct. Not advisable with snow cover
RESPONSE TIME:	Not critical[1]	

CODE: GLG 2

OBJECTIVE: Geologic Mapping 1:250,000

DESCRIPTION: Geologic maps at 1:250,000 have been compiled for nearly 15% of U.S.[1] Such maps are especially important for regions where existing maps are either unavailable or insufficiently accurate for mineral and oil exploration.[1] (See also GLG 1)

METHOD: (See GLG 1)

PRIMARY SENSING TECHNIQUE: Visual (color) imaging[1,3,46] (metric quality desireable)[1]
Radar Imaging[1,3,9,48]

SUPPLEMENTARY SENSING TECHNIQUE: Thermal IR Imaging[3,47]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Visual (color) Imaging	6-15m[1]	6m (30m[1])
Radar Imaging	30 m[1]	15m (60m[1])
Thermal IR Imaging		15m (150m)
THERMAL RESOLUTION:		0.5°C
SUN ANGLE:	30-60° [1]	20-40° and 60-90°
SWATH WIDTH:	90 km[1]	
LOCATION TO BE OBSERVED:	Entire USA, Alaska and Hawaii	
OBSERVATION SCHEDULE:	Once at each Sun angle[1] Coverage desirable during autumn[3]	Once at each Sun angle during late summer or autumn
RESPONSE TIME	Not critical[1]	

CODE: GLG 3

OBJECTIVE: Locate Mineral Deposits

DESCRIPTION: The purpose is to increase our supply of available natural resources. During the past 30 years the U.S. alone consumed more minerals and fueld than the entire world in all previous recorded history.[10] The U.S. is expected to double its present mineral consumption in the next 15-25 years.[10] Many structures are large and subtly expressed and hence often go unrecognized[10]-- a number of previously unknown features were spotted on Gemini and Nimbus photos.[10] Most metallic mineral deposits are associated with fractures or fracture systems in the Earth's crust--many deposits occur at intersecting fractures.[44] Often mineral deposits are expressed by topographic anomalies.[10] Geologic indicators provide evidence that allows an inference of the presence of certain minerals.[3]

METHOD: Locate favorable lithology.[3] Detect zones of alteration (gossans) and color staining.[3] Recognize faults and fault systems, dikes, veins, pegmatites.[3,10] Color photography is useful--color staining (alteration) has led to discovery of many deposits.[10] Color photography excells in information capacity, simplicity, and reliability[3] and IR readily identifies thermal features, but can be poor in defining geological features.[47] Detect thermal anomalies associated with deep seated igneous bodies[3] -- some sulfide bodies produce heat through oxidation and may destroy permafrost.[44] Gemini photographs show a correspondence between, for example, ultrabasic rocks and occurrences.[46] Radar imaging can be a very useful tool for distinguishing various lithologic units,[3] and it shows topography clearly--especially traces of fault systems.[15] VLF radio techniques offer a possibility of penetrating below surface.[3,49]

PRIMARY SENSING TECHNIQUE: Visual Color Imaging[1,3] (metric quality desirable)

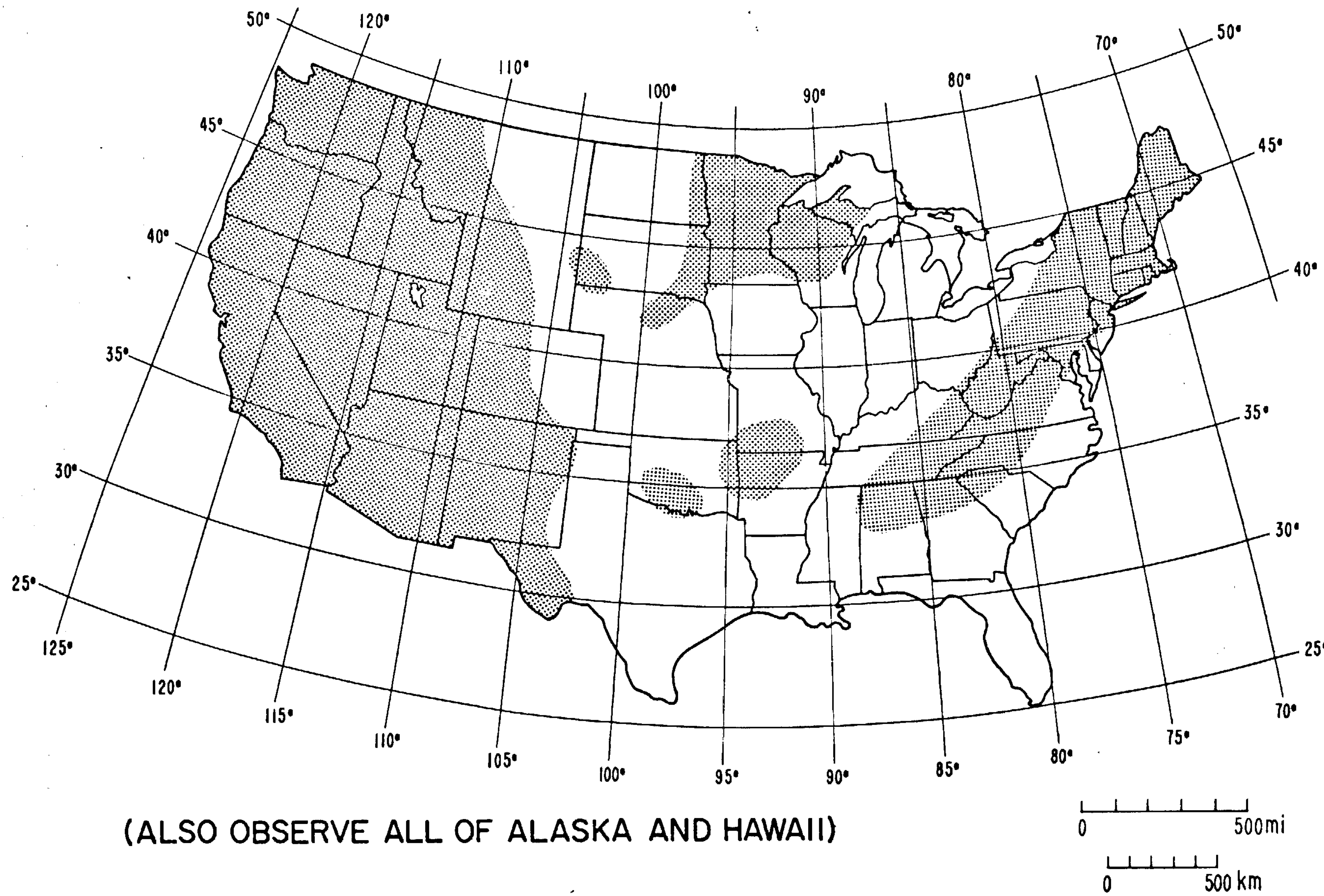
SUPPLEMENTARY SENSING TECHNIQUES: Radar Imaging[5,15,48,3]

ALTERNATE SENSING TECHNIQUES: IR Imaging[1,5,47,3] 3-4 - 4.2 μ and 8-14μ[1]
Passive Microwave Imaging [5,3]
Absorption spectrophotometry[3]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Visual (color) Imaging	6-30m[1] 3-30m[3] 100-450m[11]	6m (90m[1])
Radar Imaging	3-30m[3] 100-450m[11]	30m (90m)
Thermal IR Imaging	300m[1] 3-30m[3] 30-300m[3] 100-450m[11]	30m (300m)

Passive Microwave Imaging		30m (300m)
THERMAL RESOLUTION:	$0.5^{o}C$[1]	
SUN ANGLE:	30^{o} and 60^{o}[1]	$20\text{-}40^{o}$ and $60\text{-}90^{o}$
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	See map	
OBSERVATION SCHEDULE:	At least twice, once ate each Sun angle[1] coverage most desirable during autumn[1,3] prefer Sept. or Oct.	July-October, preferably Sept. or Oct.
RESPONSE TIME:	Not critical[1]	

GLG 3 MINERAL DEPOSITS



(ALSO OBSERVE ALL OF ALASKA AND HAWAII)

CODE: GLG 4

OBJECTIVE: Oil Exploration

DESCRIPTION: The purpose is to increase petroleum reserves by locating new oil fields. By the year 200, petroleum demands will be 40 times the 1960 U.S. production.[3] Orbital observations should improve precision of petroleum inventories by increasing knowledge of size of sedimentary basins, thickness of strata, characteristics of structures.[10] Three-fourths of the world's structural anomalies producing oil and gas are expressed as topographic highs.[3]

METHOD: Search for favorable rock types (porous, sedimentary rocks),[3] structural features (traps),--domes, faults, folds[3]--annular light and dark halos not visible in field but seen from above.[3] Characteristic vegetation can also be indicative (dwarfed Alaska evergreen for instance, has an affinity for shale).[3] Many petroleum deposits are localized by structures.[10,3] Space photos indicate a correspondence between surface features and major basin structures in S.W. Texas.[12] Many structures are large and subtly expressed.[10] Gemini photographs show correspondence of regional transcurrent faults to major oil fields.[46]

PRIMARY SENSING TECHNIQUE: Visual (color) imaging[1,3] (metric quality desirable)

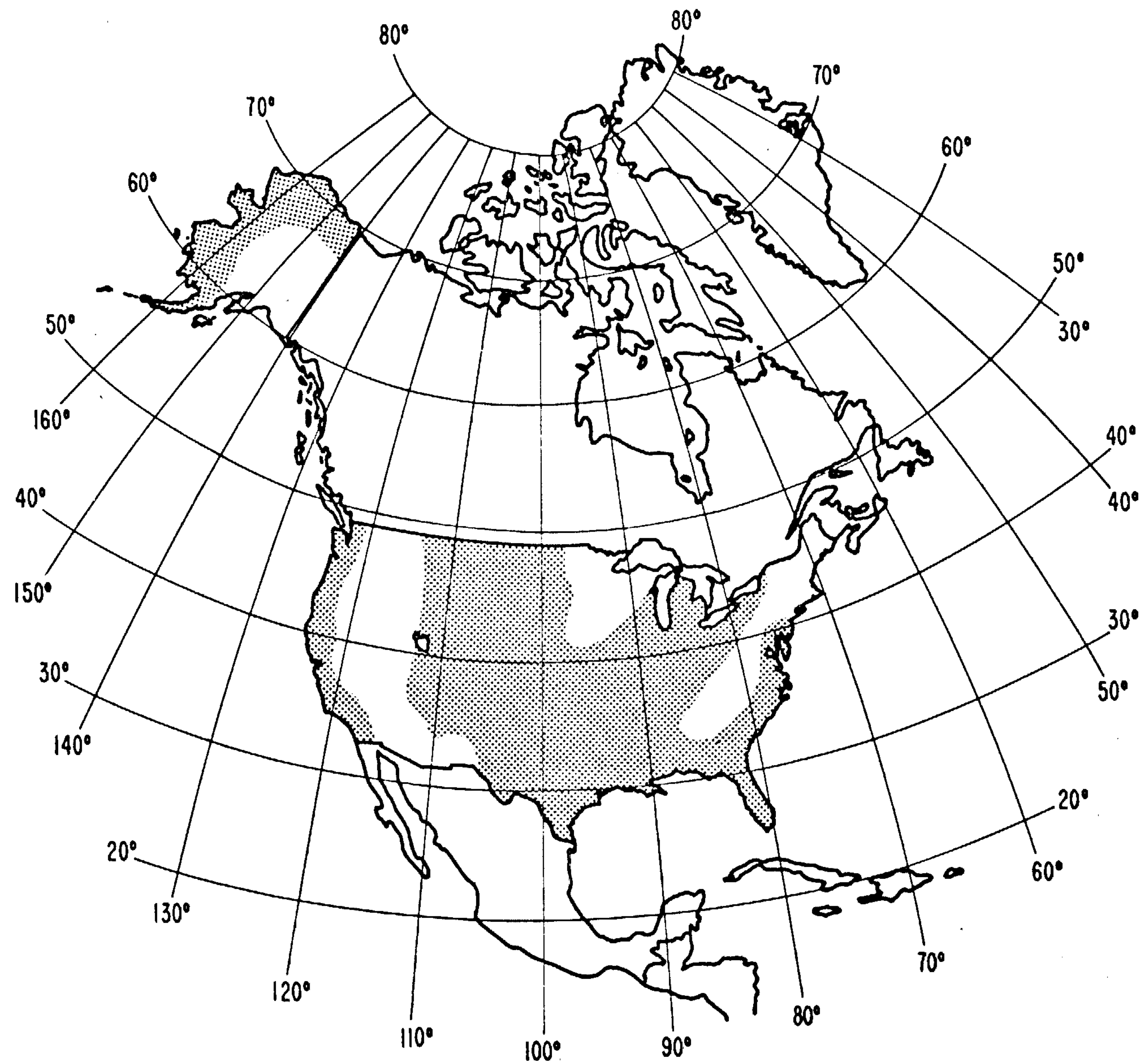
SUPPLEMENTARY SENSING TECHNIQUE: Radar Imaging[48]

ALTERNATE SENSING TECHNIQUE: Multispectral imaging

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Visual Imaging	6-30m[1] 3-30m[3] 100-450m[11]	6m (90m[1])
Radar	3-30m[3] 100-450m[11]	6m (90m)
SUN ANGLE:	30° and 60°[1] photography should be done both at a high and also a low angle[1]	20-40° and 60-90°
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	See map	

OBSERVATION SCHEDULE:	Twice, once at each Sun angle[1] observations in early and late fall most valuable	Observe twice, once at each Sun angle, during period of July through October. September and October are preferred months.
RESPONSE TIME:	Not critical[1]	
MAP SCALE FACTOR:	1:250,000[1]	

GLG 4 OIL EXPLORATION



POSSIBLE PETROLEUM AREAS

CODE: GLG 5

OBJECTIVE: Geothermal Power Sources

DESCRIPTION: Search for geothermal anomalies that could conceivably be used as sources of geothermal power.[10,44] It may be possible to detect some "low level" anomalies not readily detectable by aircraft.[10]

METHOD: IR systems should be used to scan tectonic areas for "low level" and unrecognized thermal anomalies.[44,10] Visual imaging may be useful as an alternate technique, since anomalous snow melt patterns may reflect geothermal energy.[50] Observations of snow melting patterns in Ireland have already been successful in locating thermal anomalies.[44]

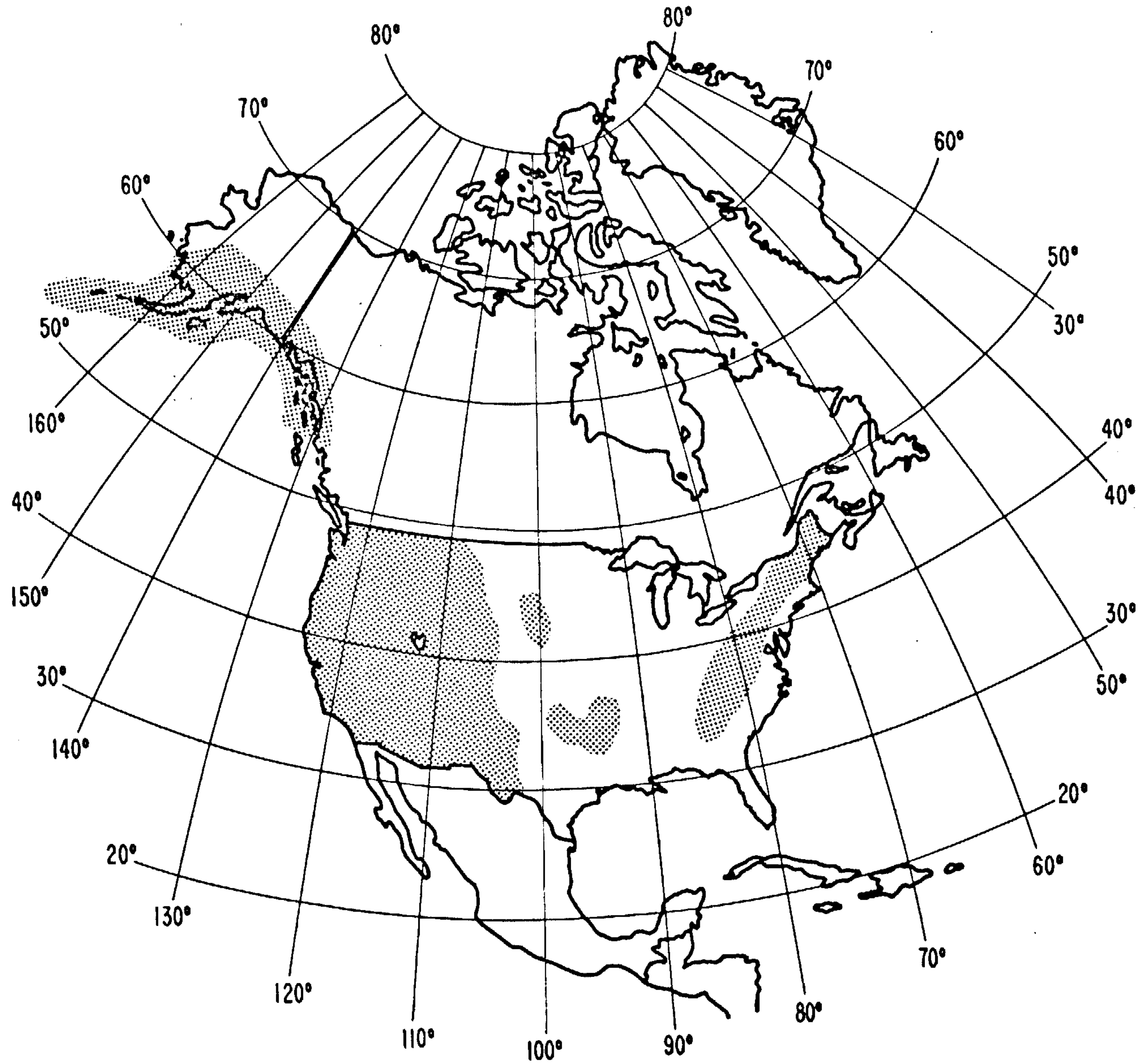
PRIMARY SENSING TECHNIQUE: IR imaging,[10,44] 8-13 μ

ALTERNATE SENSING TECHNIQUE: Visual imaging,[44] black and white or color

MEASUREMENT PARAMETERS:

		RECOMMENDED VALUES
GROUND RESOLUTION:		
Thermal IR Imaging	120-150m[1] 300m[1] 150-300m[1] 300-3000m[3]	120m (300m)
Visual Imaging	6-20m[1] 300-3000m[3]	120m (300m)
THERMAL RESOLUTION:	$0.5^{\circ}C$[1]	$0.5^{\circ}C$ ($1^{\circ}C$[1])
SUN ANGLE:		$30-90^{\circ}$
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	See map	
OBSERVATION SCHEDULE:	Once seasonally[1]	100% coverage one time. For IR, look during the summer; for visual when partial snow cover exists.
RESPONSE TIME:	Not critical[1]	

GLG 5 GEOTHERMAL POWER SOURCES



(ALSO INCLUDES HAWAII)

CODE: GLG 6

OBJECTIVE: Earthquake Belt Reconnaissance

DESCRIPTION: Survey earthquake zones and areas of potential earthquake activity.[10] Study the origin and extent of transcurrent faulting[11] and locate and map new and unrecognized faults.[1] Gemini photography indicates many Earth fractures have not been recognized.[1,46] Knowledge of fracture patterns in populated areas would help locate cultural areas possibly endangered.[1] Engineers planning highways, bridges, dams, and buildings should know location of fractures.[10] Assist in correlating lithologic units across major faults.[10]

METHOD: Radar images show topography clearly--especially traces of fault systems.[15] Radar provides "side-light" effects, similar to lighting effects of morning and evening Sun which accentuate low fault scarps and can operate through clouds and at night.[15] IR systems can be used to detect thermal anomalies and hot springs along faults.[15] Color photography brings out tonal, textural, and structural variations and provides clues to fracture lineaments.[1] Multispectral imaging gives greater enhancement over normal panchromatic photographs and can be used to discriminate various rock and soil units.[15]

PRIMARY SENSING TECHNIQUE: Radar imaging[15,48]

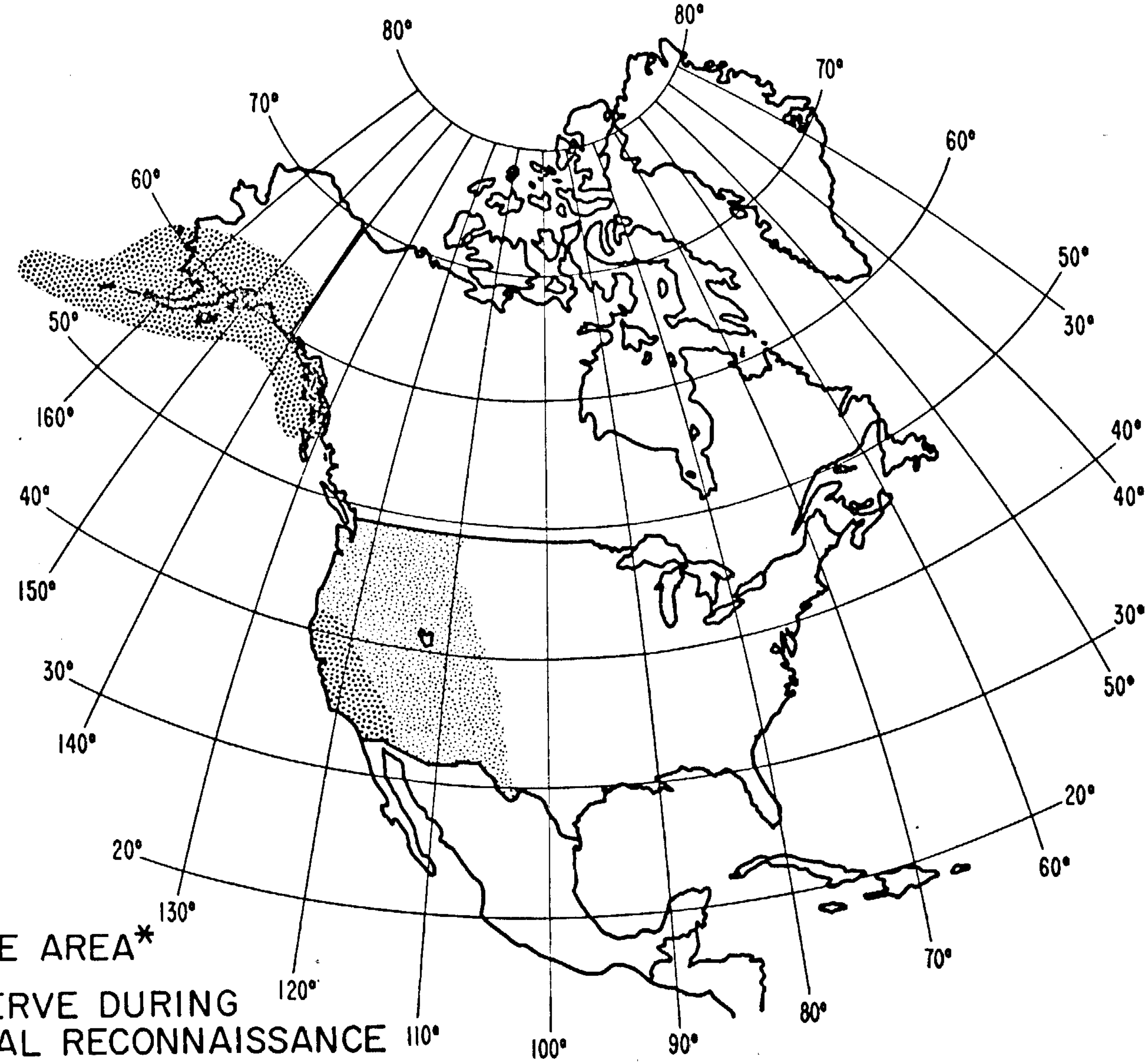
SUPPLEMENTARY SENSING TECHNIQUES: Visual (color) imaging[15] - both vertical and oblique[1]
IR imaging[15] - 3.5-4.2 μ and 8-12 μ [1]

ALTERNATE SENSING TECHNIQUE: Multispectral Imaging[15]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Radar	0.2-3.2 km[3] 100-450m[11]	30m (150m)
Visual Imaging	30m[1] 150-3000m[3] 100-450m[11]	30m (180m[1])
Thermal Imaging	150-300m[1]	150m (300m)
THERMAL RESOLUTION:	0.25-0.5°C[1]	0.5° (1°C)
SUN ANGLE:	60-90° [1]	20-40° and 60-90°
SWATH WIDTH:	90 km[1]	
LOCATION TO BE OBSERVED:	See map	

OBSERVATION SCHEDULE:	Once[1]	Radar coverage once Twice- once at each Sun angle for visual imaging, during July-Oct. Thermal IR coverage once, during July-Oct.
RESPONSE TIME:	Not Critical[1]	
MAP SCALE FACTOR:	1:250,000[1]	

GLG 6 EARTHQUAKE-BELT RECONNAISSANCE



PRIME AREA*

OBSERVE DURING INITIAL RECONNAISSANCE SURVEY

(*ALSO INCLUDES HAWAII)

CODE: GLG 7

OBJECTIVE: Volcanic Belt Reconnaissance

DESCRIPTION: Inventory known and possible areas of volcanic activity. Sudden volcanic eruptions in previously dormant belts take a heavy life and property toll.[1] Define areas which should be periodically surveyed. Provide data for expanding research in vulcanology.[1] Provide pre-eruption base line data with which future reconnaissance data could be compared.[1] Predict routes of lava advance. Anomalously high IR emission has already been detected in many areas[51] including several dormant or inactive areas.[51]

METHOD: Use IR scanners to locate and define anomalies [12,10,11] especially around volcanic areas[1] and hydrothermally active areas.[10] Observe deformation and areal extent of mountain systems.[3] Radar can be very valuable for detecting subtle lithology changes, regional structure studies, and supressing distracting and redundant detail (vegetation, etc.).[48]

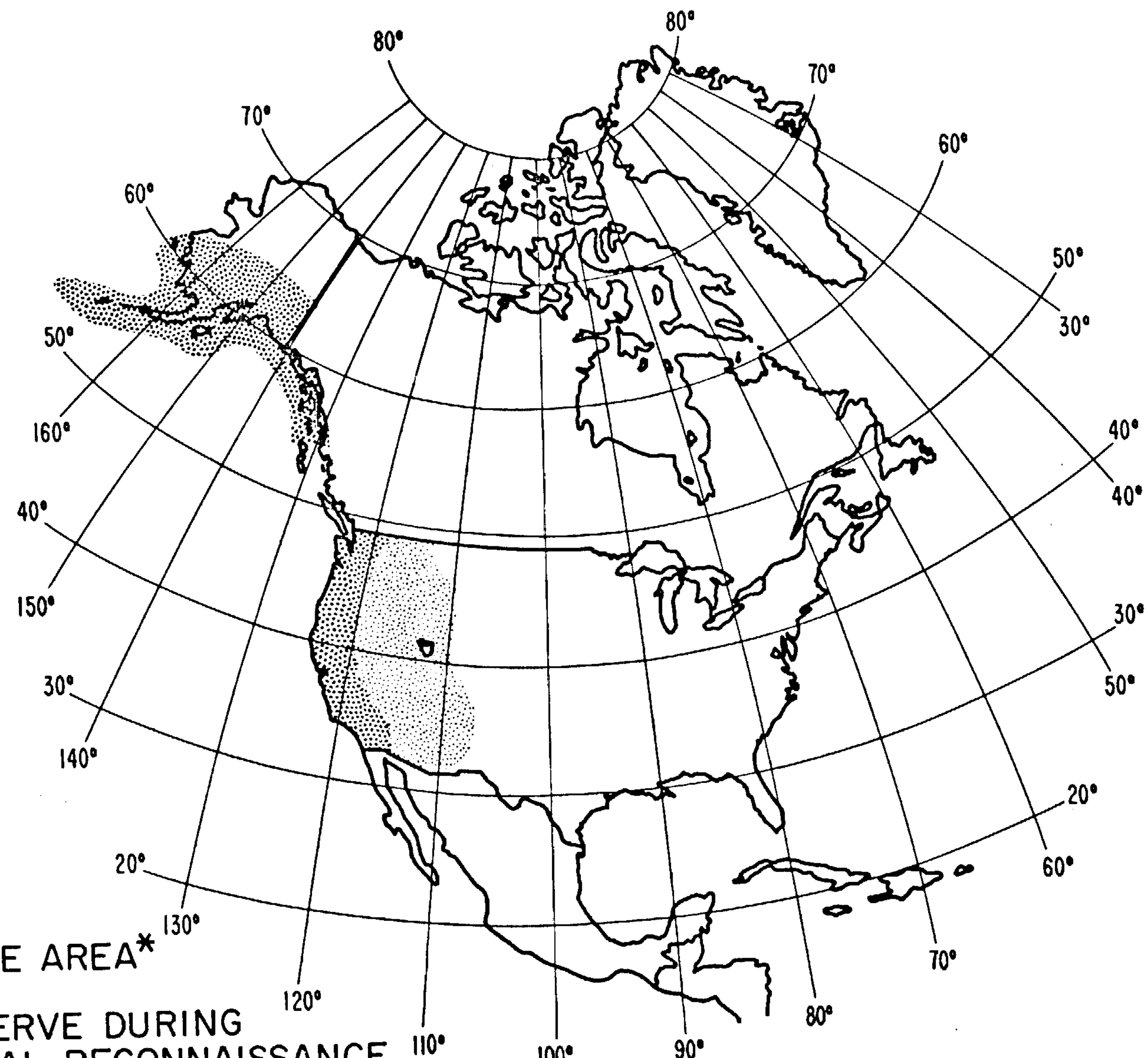
PRIMARY SENSING TECHNIQUE: IR imaging[10], 3.4 - 4.2 and 8 - 12μ[1]

SUPPLEMENTARY SENSING TECHNIQUE: Radar imaging [3,48]

ALTERNATE SENSING TECHNIQUE: Visual (color) imaging[3]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Thermal IR Imaging	150-300m[1] 300-3000m[3]	150m (3000m)
Radar Imaging	300-3000m[3]	30m (150m)
Visual (color) Imaging	300-3000m[3]	30m (120m)
THERMAL RESOLUTION:	$1^{\circ}C$[1]	
SUN ANGLE:	20-40° and 60-90°	
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	See map	
OBSERVATION SCHEDULE:	Once[1]	Obtain 100% coverage once with each sensor type. IR imaging during summer (no snow), visual summer or early fall (no snow or else partial snow cover).
RESPONSE TIME:	Not critical[1]	

GLG 7 VOLCANIC-BELT RECONNAISSANCE



PRIME AREA*

OBSERVE DURING INITIAL RECONNAISSANCE SURVEY

(*ALSO INCLUDES HAWAII)

CODE: HYD 1

OBJECTIVE: Snow Cover Survey

DESCRIPTION: Water supply in the arid lowland regions of the western U.S. depends heavily on winter precipitation in adjacent mountains or other humid regions. Snow surveys are presently conducted on the ground to determine the probable adequacy of water supply for summer irrigation needs[25] and for run-off predictions used in regulating hydroelectric power generation.[5]

METHOD: The information desired includes areal extent of snowpack, depth of snowpack, and moisture content. Information on the surface temperature of the snowpack would aid in estimating melt rates. Snowpack area can be determined from color or black-and-white visual imagery, although discrimination between clouds and snow may be difficult. Depth of snow cannot at present be determined remotely, although pulse radar techniques may hold some promise.[27] Moisture content cannot be remotely sensed with present-day techniques, although there is some evidence that passive microwave radiometric measurements may be able to determine snow wetness factors.[28]

PRIMARY SENSING TECHNIQUES: Color or black-and-white visual imaging.

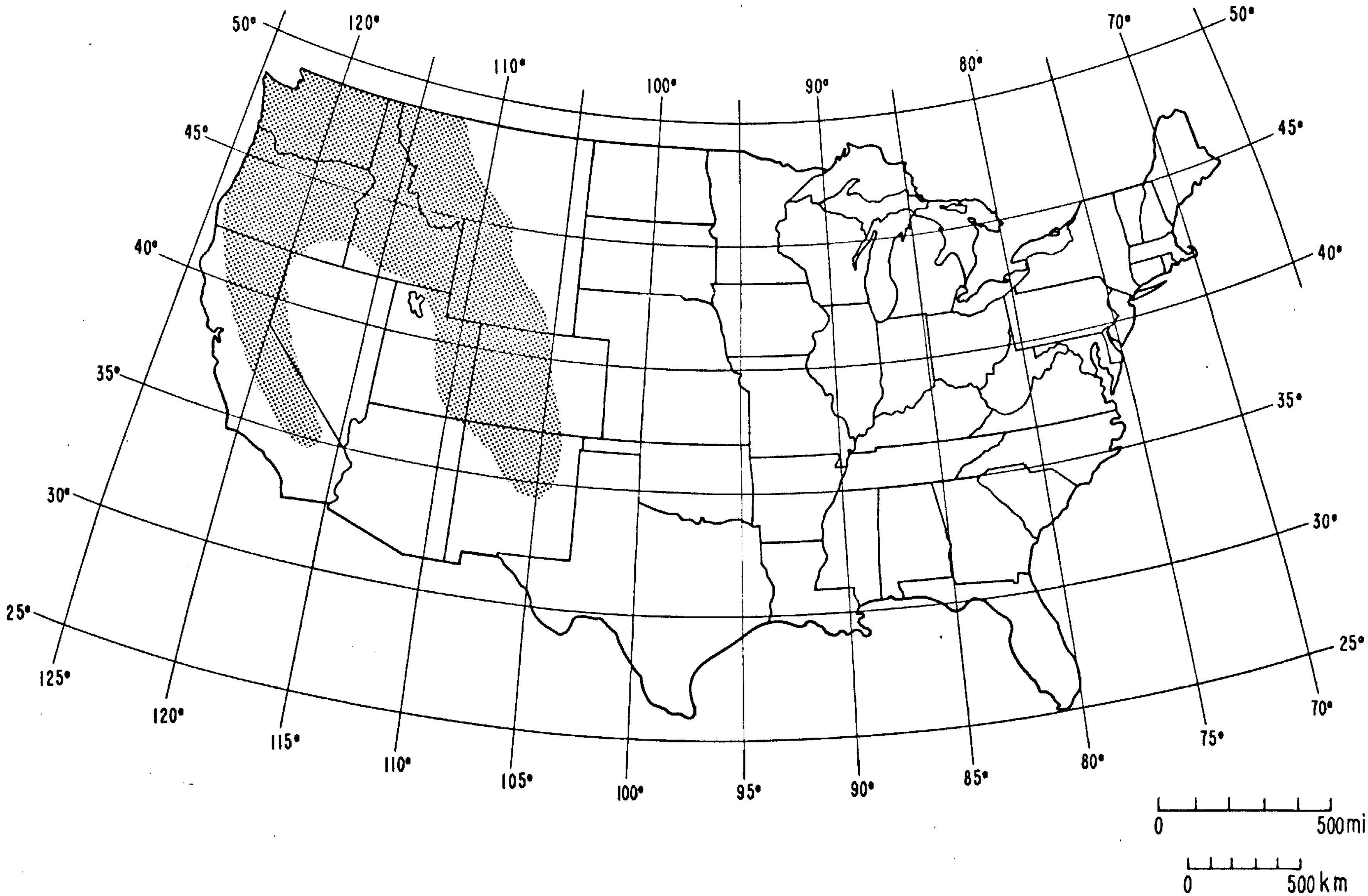
SUPPLEMENTARY TECHNIQUES: Thermal IR imaging.
Pulse radar.*
Passive microwave radiometry.*

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Optical	15m[5] 30-90m[1] 60m[2]	15m (90m)
Thermal IR	900m[5]	
THERMAL ACCURACY (ABSOLUTE):	1°C[5]	
SUN ANGLE:	30°-60°[1]	30-60°
SWATH WIDTH:	180 km[1] 800 km[5]	180 km
LOCATION TO BE OBSERVED:	West and North-West U.S.[5] Up to 90° latitude[1] Temperate region snow zones	

*These techniques require substantial further development.

OBSERVATION SCHEDULE:	At least once per 30 days.[1] Once per 2 weeks from Dec. 1 to May 15. From Sept. to April, once/day during critical periods.[5]	Once per two weeks from Dec. 1 to June 30, capability of daily observations during periods of rapid melt desirable.
RESPONSE TIME:	2 to 14 days[1] Not critical[5] 4 days	4 days.

HYD I SNOW COVER SURVEY



CODE: HYD 2

OBJECTIVE: Monitor River and Lake Ice

DESCRIPTION: Information on the extent of ice formation on navigable inland waterways is needed to plan icebraking schedules and decide on the feasibility of navigation during critical periods. Information about river ice will help in estimating the likelihood of flooding due to temporary ice jams during spring break-up.

METHOD: For navigation purposes, knowledge of the presence and location of ice of thickness greater than nine inches is needed. Ice blocks of dimensions greater than 50 feet in rivers and greater than 200 feet in the Great Lakes should be detected.[2] The presence of ice may be detected by reflectivity variations in visual, near-IR, and radar wavelengths and by variations in brightness temperature in the thermal IR and passive microwave regions. All-weather capability would be very desirable.

RECOMMENDED SENSING TECHNIQUE: Passive Microwave Imaging
Microwave Radar

ALTERNATE SENSING TECHNIQUES: Thermal IR Imaging
Visual imaging, color or black-and-white

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
All Sensors	30-90m[1] 15-60m[2,3]	15m (90m)
THERMAL RESOLUTION:	0.5-1.0°C[1]	
SUN ANGLE:	30-60°[1]	
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	Great Lakes and major river systems above 40° N.[2,3]	
OBSERVATION SCHEDULE:	Weekly during spring and fall[2]	Weekly during periods Nov. 15--Jan. 15, and March 1--April 30.
RESPONSE TIME:	3 days for navigation purposes	

CODE: HYD 3

OBJECTIVE: Locate Areas of Ground-Water Discharge

DESCRIPTION: Identification of areas of ground-water discharge to surface-water bodies is important because it gives clues to areas underlain by productive aquifers that may be capable of supplying large amounts of water.[25] Early surveys might most profitably be conducted in arid or semi-arid areas such as the southwestern United States, especially if perennial or ephemeral springs can be located.[1]

METHOD: Areas of ground-water discharge may be indicated by tonal anomalies and patterns on visual color imagery, or by relative thermal contrasts between cool ground-water flow and warmer background on thermal IR imagery. Airborne IR instrumentation has been used quite successfully in detecting freshwater springs along the shores of Hawaii.[54] Thermal IR imagery is best obtained at night as interfering reflected solar radiation is thereby eliminated.[55]

PRIMARY SENSING TECHNIQUE: Thermal IR imaging

SUPPLEMENTARY SENSING TECHNIQUE: Color visual imaging.

MEASUREMENT PARAMETERS:	RECOMMENDED VALUES
GROUND RESOLUTION:	
Optical	3-6m[1]
Thermal IR	30-90m[1]
THERMAL RESULUTION:	0.5-1.0°C[1]
SUN ANGLE, Optical:	60-90°[1]
IR:	Night-time[55]
SWATH WIDTH:	45 km[1]
LOCATION TO BE OBSERVED:	Up to 70° N. latitude, selected areas in North America[1]
OBSERVATION SCHEDULE:	At least twice each season[1]

CODE: HYD 4

OBJECTIVE: Monitor Network of Hydrological Stations

DESCRIPTION: To provide basic hydrological data for water management.

METHOD: In situ stations make direct measurements of stream flow, water quality, river height, and other hydrological parameters which are transmitted to satellite for storage and relay as appropriate.[1]

MEASUREMENT PARAMETERS

LOCATION TO BE OBSERVED:	River systems, lakes, drainage basins, etc.
OBSERVATION SCHEDULE:	All year Station readout at least once/day.[1]

CODE: AGF 1

OBJECTIVE: Crop Inventory and Forecast

DESCRIPTION: Information on acreage planted to various crops and forecasts of expected yield are of considerable importance to agri-business* as well as to the farmers themselves for planning their marketing strategy.[40] The USDA and Bureau of the Census utilize crop data in preparation of census and crop reports and forecasts, and the USDA needs the data also for the administration of production adjustment and price and market stabilization programs.[2] The observation schedule for this objective is taken from Addendum A of Reference 1 which describes observations of the Corn Belt, Mississippi Delta/East Texas/Louisiana, and Great Plains areas to monitor grain, soybean, and cotton crops.

METHOD: The inventory function requires the location, area measurements, and identification of crops. The yield forecast is based on assessments of factors such as losses to weeds, diseases, and insects; and stand density. Color visual imagery can supply most of the information. Species identification and vigor determination would be facilitated by multi-spectral imaging in the visual and IR bands. Metric quality is desirable for accurate area determinations.

PRIMARY SENSING TECHNIQUE: Multispectral imaging, 5 bands in visual and IR, (metric quality desirable)[24]

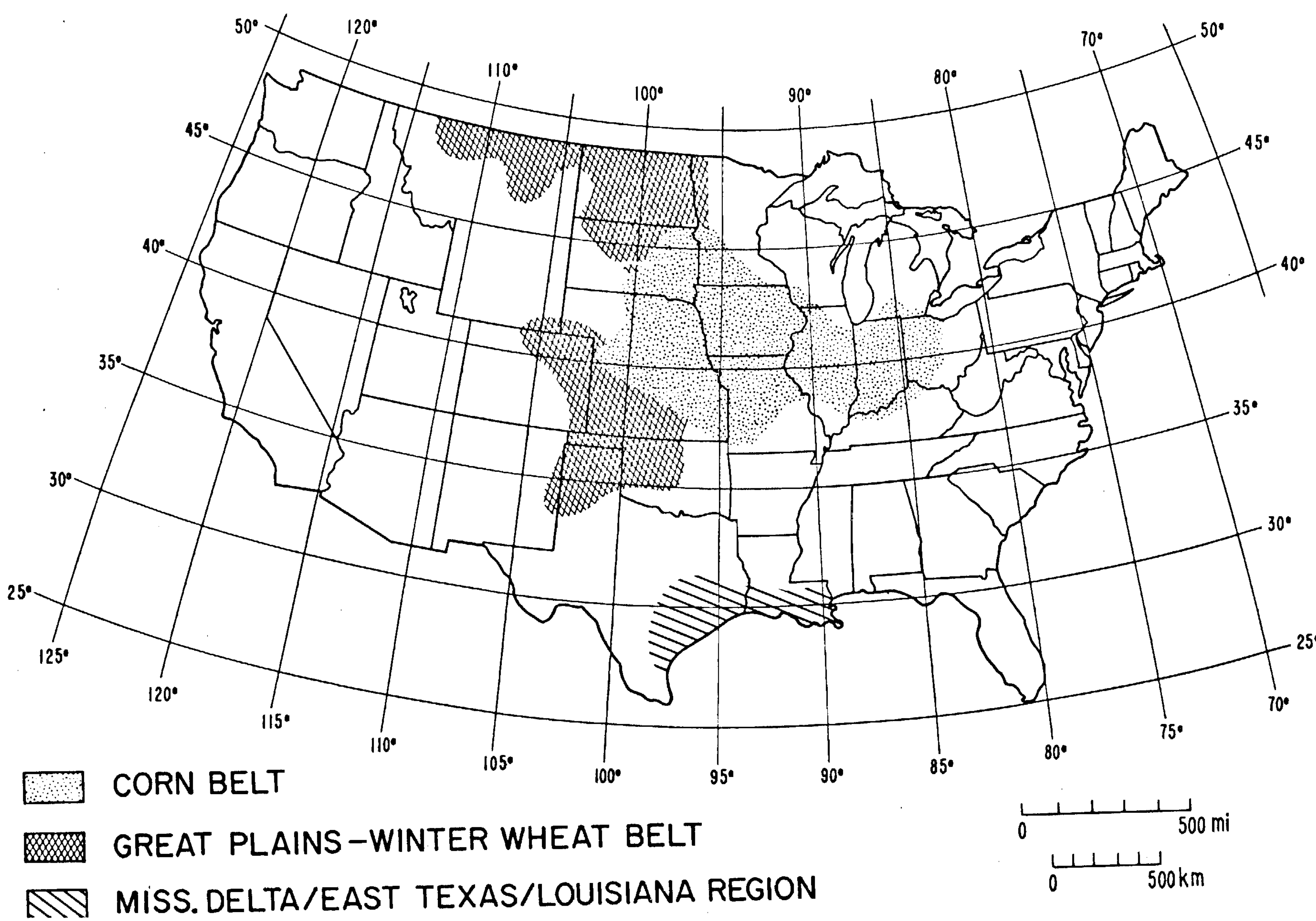
ALTERNATE SENSING TECHNIQUES: Color photography[1]
Three-band multispectral imaging, visual and near-IR[24]
Multi-frequency poly-polarization radar[24]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Optical	30 ± 6m (1.5-6m for detailed surveys)[1] 1.5-6m (15-30m still useful)[3] 20m[24] 60m (multispectral)[1]	15m (60m)

*The term "agri-business" as used here includes business which provide goods and services to farmers and which transport, process, store, and market agricultural products.

SUN ANGLE:	60-90°[1]	RECOMMENDED VALUES
SWATH WIDTH:	45 km[1]	
LOCATION TO BE OBSERVED:	Corn Belt; Mississippi Delta/East Texas/Louisiana; and winter wheat areas of the Great Plains.[1] (See map)	
OBSERVATION SCHEDULE:		
Frequency of observation:	14 days[1] 2 days (wheat rust)[5] 7 days (rice)[5]	14 days
Time period for observation:	(Information given in Reference 1 for wheat rust and rice is not shown here for the sake of brevity.)	
Corn Belt[1]:	Mid-March to Mid-April, May 1-10, June 25-July 5, July 15-August 5, August 15 to September 10.	
Mississippi Delta/East Texas/Louisiana[1]:	May 1-15, June 15-20, August 15-September 10, October 1.	
Great Plains[1]:	July 15-August 15, October 1-November 1, March 20-April 10, May 1-15, June 1-10, June 25-July 10.	
RESPONSE TIME:	30 days[1] 7-30 days (wheat rust)[5] 30 days minimum (rice)[5]	14 days

AGF I CROP INVENTORY AND FORECAST



CODE: AGF 2

OBJECTIVE: Forest Mapping

DESCRIPTION: The United States has no complete, detailed, and reliable map of the location and distribution of its forests.[2] Forest surveys are presently made in each state every 8-10 years[19] by the U.S. Forest Service and are supplemented by state agencies. Such information is vital to efficient management of the nation's forest resources.

METHOD: The information required is the location and distribution of forests with at least a gross compositional breakdown (such as hardwoods, and mixed). A further breakdown into distribution by species would increase the usefulness of the information. The most recent investigations indicate that multispectral imaging in the green, red and near-IR regions of the spectrum is the most useful remote sensing technique.[16] Detailed composition determinations will require observations at appropriate parts of the growing season.[16,3] Differentiation of gross timber types can be achieved on aerial photography using color IR film and appropriate filters.[23]

RECOMMENDED SENSING TECHNIQUE: Multispectral imaging in red, green and near-IR.[16] (Metric quality desirable)

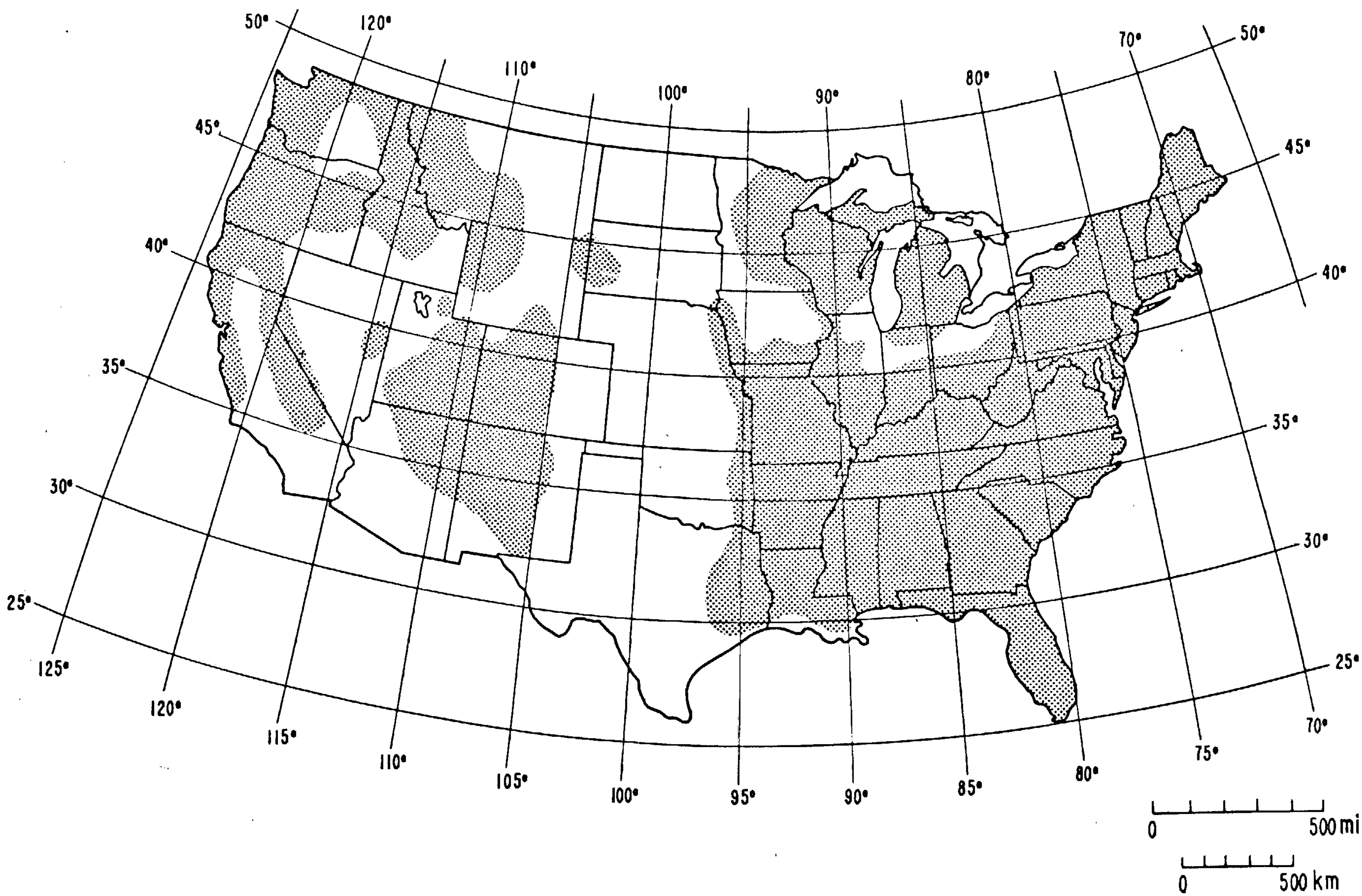
ALTERNATE SENSING TECHNIQUE: Color visual imaging
Black-and-white visual imaging

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Optical	60-120m[2] 3-30m[3] 30-120m (15-30m for gross composition)	15m (120m)
SUN ANGLE:	Local mid-morning[16] 60-90°[1]	60-90°
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	Forested areas of the U.S.	See map.
OBSERVATION SCHEDULE:	Once (100%) per 5 years.[1,2] Observe during spring (flush of new growth) or fall (autumn coloration)[6]	Once per week during months of March, April, May, Sept., Oct., Nov., One observation per 5 years.*

RESPONSE TIME:	6 months[2] Not critical[1]	6 months

*Experience gained from interpretation of the first cycle of observations would allow improvement of the observation schedule.

AGF 2 FOREST MAPPING



CODE: AGF 3

OBJECTIVE: Timber Inventory

DESCRIPTION: This objective is an extension of Forest Mapping (AGF 2) toward a more quantitative evaluation of forest resources. The purpose is to provide estimates of timber volume by species.

METHOD: Crown diameter, crown density, and tree height information is desired. Information on tree vigor and the effects of disease, insect infestation, and forest fires is also important. The measurement of tree height is probably not feasible. Color or multispectral imagery may provide data related to vigor. Fire, insect, and disease losses would be observable on color or multispectral imagery and to some extent on black-and-white. High resolution color or black-and-white imagery will be required for crown diameter and density. Sampling observations would be sufficient, 100% coverage is not required.

RECOMMENDED SENSING TECHNIQUE: Multispectral imaging in red, green, and near-IR.[16]

ALTERNATE SENSING TECHNIQUES: Color visual imaging
Black-and-white visual imaging Radar[3]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Optical	15-30m; 1.5-15m (highly accurate production estimates)[1]	1.5m (30m)
SUN ANGLE:	60-90°	
SWATH WIDTH:	180 km[1]	
LOCATION TO BE OBSERVED:	At least 10% sample of forested areas of U.S.	See map for AGF 2
OBSERVATION SCHEDULE:	Once per 5 years[1,2] 1% sample for growth or destructive trends[1,2] 10% sample for stand density[2]	Obtain at least 10% coverage of forested areas during July and August.
RESPONSE TIME:	6 months[2] Not critical	6 month

CODE: AGF 4

OBJECTIVE: Forest Fire Detection

DESCRIPTION: Aerial surveillance is currently used for fire observation,[1] and an airborne thermal IR scanner was used successfully during the summer of 1967 for fire detection.[43] It appears that airborne systems would be most practical for frequent precise up-dating of known fires. For fire detection on a periodic basis over large areas, spacecraft systems may be very useful. Early discovery and rapid reporting are essential to the success of such a system.

METHOD: The presence of fires can be indicated by sensing the resulting thermal anomalies. Operational goals for an airborne system are to detect fires smaller than one square foot in area and locate them within 500 feet relative to local topography.[21] Lesser capabilities such as detection of 20 feet diameter fires with large temperature differentials over background, or larger fires with smaller average temperature differential, still would be useful.[2] Thermal resolution must be high enough to show topographic detail for location purposes.

PRIMARY SENSING TECHNIQUE: Thermal IR imaging, 4.5-5.3μ[2,22]

ALTERNATE SENSING TECHNIQUE: Passive microwave imaging[3]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND / THERMAL RESOLUTION:		
IR & Microwave	60m (large fires)[2] 6m/200°C ΔT or 30m/10°C ΔT (small fires)[2] 6m/20°C ΔT or 18m/2°C ΔT (sleeper fires)[2] 100m/1°C[1] 30-300m[3]	18m (100m)
THERMAL RESOLUTION: (for topography)	±1.0°C[1]	±1.0°C
SWATH WIDTH:	90 km[1]	
LOCATION TO BE OBSERVED:	Forested areas of U.S	See map for AGF 2

OBSERVATION SCHEDULE:	At least once per day for detection, every 4-6 hrs for incipient-fire updating, hourly for active and small fires.	Daily observations during fire season. The fire season may be defined as July thru Oct. In actual practice observations might well be planned on a request basis in response to local conditions.
RESPONSE TIME:	1 hr for large and small fires, 4 hrs for sleeper fires.[2]	1 hr (4 hrs)

CODE: AGF 5

OBJECTIVE: Rangeland Mapping and Assessment of Forage Potential

DESCRIPTION: Efficient management of the rangeland resource requires comprehensive and timely information on range conditions. Better knowledge of the location and distribution of range areas with information on the carrying capacity for livestock will allow more effective use of the resource. The forage potential of range areas varies from year to year as well as during the grazing season in response to moisture conditions and degree of use.

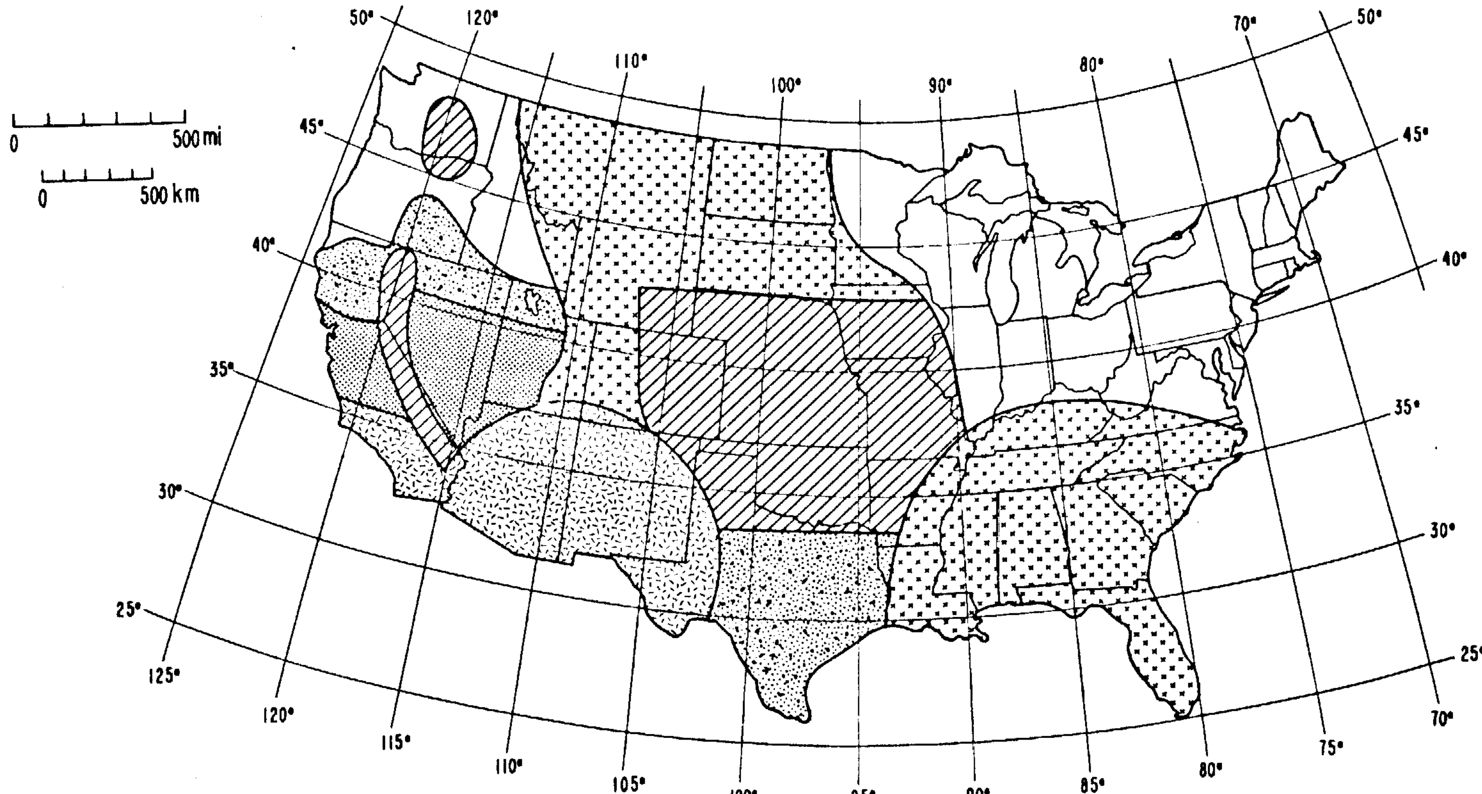
METHOD: The information desired includes the identification and location of vegetation types, assessment of vegetation density and vigor, determination of the appropriate time to begin grazing in particular areas, and detection of overgrazing conditions.[1,18] Photography using color IR film at appropriate times during the growing season has been the most effective remote sensing tool in feasibility investigations.[18]

PRIMARY SENSING TECHNIQUE: Multispectral imaging in red, green, and near-IR bands[18] or Color IR photography.[18]

ALTERNATE SENSING TECHNIQUE: Color visual photography.

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Optical	10-30m[1] 3-7.5m (detailed survey)[18] 15-30m (vegetation-soil boundaries, over-grazing)[18] 90-120m (Identification of forests, brushland, grassland on regional scale)[18] 6-30m[3]	10m (120m)
SUN ANGLE:	$60-90^{o}$[1]	
SWATH WIDTH:	90 km minimum[1]	
LOCATION TO BE OBSERVED:	Up to 50^{o} N latitude	See map.
OBSERVATION SCHEDULE:	At least twice per year during mid-spring and late summer.[1]	See map.
RESPONSE TIME:	4 to 8 weeks (6 weeks average)	6 weeks

AFG 5 RECOMMENDED RANGELAND OBSERVATION TIMES



OBSERVATION TIMES

MARCH — ONCE APPROX FEB 15; ONE PER WEEK IN MARCH; ONCE APPROX APRIL 15

APRIL — ONCE APPROX MARCH 15; ONE PER WEEK IN APRIL; ONCE APPROX MAY 15

MAY — ONCE APPROX APRIL 15; ONE PER WEEK IN MAY; ONCE APPROX JUNE 15

JUNE-JULY — ONCE APPROX JUNE 1; ONE PER WEEK FROM MID-JUNE TO MID-JULY; ONCE APPROX SEPT 1

JULY-AUGUST — ONCE APPROX JULY 1; ONE PER WEEK FROM MID-JULY TO MID-AUG; ONCE APPROX SEPT 1

CODE: GEG 1

OBJECTIVE: Small Scale Geographic Mapping (Scale Factor 250,000)

DESCRIPTION: To develop small scale generalized maps, rapidly prepared (in a few weeks for some purposes), to provide a world-wide base map series. To outline and classify land forms and general features of broad areas for environmental analysis and to detect cultural changes. Extend the knowledge and accuracy of global topography. Revise and update existing maps. Performance of this objective for the continental U.S. alone is of relatively low priority. Coverage of Alaska and the remainder of the North American continent is more urgently needed.

METHOD: Visual color and black and white high resolution photography can satisfy most cartographic requirements to allow photogrammetric mapping of large areas on an economic basis. Infrared, multi-spectral and radar imagery can measure special characteristics or penetrate cloud cover.

PRIMARY SENSING TECHNIQUES: Visual color imaging
(Metric accuracy may be a specific requirement)

SUPPLEMENTARY SENSING TECHNIQUES: Black and White visual imaging
Multispectral Imaging
Radar imaging

MEASUREMENT PARAMETERS:	RECOMMENDED VALUES	
GROUND RESOLUTION*:	50 m for 1·10^6,[39,57] 12.5 m for 1·250,000[39,57]	
SWATH WIDTH:	320 km at 1:1,000,000 112 km at 1·250,000	
SUN ANGLE:	30 to 60°[1]	
LOCATION TO BE OBSERVED:	North American Continent[1]	
OBSERVATION SCHEDULE:	Initial four season coverage. Updating at 6 month to 5 year interval.	
RESPONSE TIME:	Not critical[1]	Varies with the purpose of the map-a few weeks for some purposes.

*Map Accuracy Requirements[52,53]

Map Scale	Std Error(a) Position	Ground(b) Resolution	Contour(c) Interval	Std Error(a,d) Elevation
1,000,000	500 meters	50 meters	500 meters	250 meters
250,000	125	12.5	100	50
			50	25

(a) Metric quality requirement from National Map Accuracy Standards as of June, 1947.[56]

(b) No absolute relationship exists between map scale and the resolution or scale of the photography used in compiling the map.[52] The factor of 10 over the position requirement should satisfy most portrayal requirements at contrast ratio levels greater than 1.3:1.(39)(57)

(c) No absolute relationship exists between map scale and required contour interval.[52] Supplementary contours are shown when basic contours do not adequately portray the surface.[52] Stereo photographs are a requirement.

(d) Metric quality requirements are that not more than 10% of the elevations checked shall be in error by more than one-half of the contour interval.[52,56]

CODE: GEG 2

OBJECTIVE: Large Scale Regional Geographic Mapping (Scale Factor 1:250,000)

DESCRIPTION: Provide accurate basic survey maps for a wide variety of Earth resources disciplines[3]. Perform periodic surveys of particular geographic indices to indicate extent and rate of change of land use. Facilitate production of standard topographic maps. Update and revise existing maps to aid in the planning and forecasting of future programs. Significant international benefits could be derived from the rapid production of complete photographic maps of underdeveloped areas around the world.

METHOD: Visual color and black-and-white photography is the principal tool required.

PRIMARY SENSING TECHNIQUES: Visual color imaging
(Metric accuracy and stereo imaging may be specific requirements)

SUPPLEMENTARY SENSING TECHNIQUES: Black and white visual imaging
Multispectral
Radar imaging

MEASUREMENT PARAMETERS:	RECOMMENDED VALUES	
GROUND RESOLUTION*:	5 m at 1:100,000 2.5 m at 1:50,000 1.25 m at 1:25,000	
SWATH WIDTH:	100 km at 1:100,000[1] 32 km at 1:50,000[1] 32 km at 1:25,000[1]	
SUN ANGLE:	30 to 60° [1]	
LOCATION TO BE OBSERVED:	Specific areas within U.S. and Alaska to complete USGS map set at large scales (1:50,000, 1:25,000)	
OBSERVATION SCHEDULE:	Complete initial coverage of specific areas with six months. Update on six month to one year interval as required.[1]	6 mos. Summer season preferred.

RESPONSE TIME:	Not critical[1]	May be as short as a few weeks.

*Map Accuracy Requirements[52,53]

Map Scale	Std Error(a) Position	Ground (b) Resolution	Contour (c) Interval	Std Error (a,d) Elevation
100,000	50	5.0	50	25
50,000	25	2.5	25	12.5
25,000	12.5	1.25	10	5

For (a), (b), (c), (d), refer to GEG 1

CODE: GEG 3

OBJECTIVE: Urban Environment[1,2,3]

DESCRIPTION: Accurate and timely information is critically needed to indicate and correlate the growth and change of the urban environment. Indications of land use, housing quality, cultural changes, and degree of industriali-zation are of great value to local and regional planners.

METHOD: Detailed information as to the location and identify of buildings, transportation routes, land use, pattern and shape of specific of specific surface configurations, population density, etc. can be obtained from frequent photographic observations made to the proper specifications.

PRIMARY SENSING TECHNIQUES: Visual infrared, multiband color imaging[1,58.60]
Black and white visual imaging

SUPPLEMENTARY SENSING TECHNIQUES: Radar Imaging[59]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:	1 to 50 meters[1,59]	
SUN ANGLE:	60-70° [1]	60-90
SWATH WIDTH:	40 km[1] No specific requirement[59] but should be maximized to reduce number of photographs for a given urban area.	
LOCATION TO BE OBSERVED:	Selected urban areas within the U.S.[1]	
OBSERVATION SCHEDULE:	Fall or spring (After foliage drop but before snow cover) Frequent observations may be required	Winter observations probably not desirable. More detailed specifications are dependent on specific characteristics to be observed
RESPONSE TIME:	Complete data sets are[59] required on a timely basis to allow wide distribution to multiple users.	

CODE: DIS 1

OBJECTIVE: Storm Damage Assessment

DESCRIPTION: Rapidly assess damage and effects of severe weather.[1,12,50] Emphasis should be placed on areas near coasts.[3] Assess damage to cultural features--especially cities. Provide information on access ways. Detect changes in coast lines, beaches, shoals resulting from storms.

METHOD: Visual color imaging very desirable.[1] Radar may be most useful due to the high probability of imaging being required during bad weather conditions.[3] Note changes in cultural and topographic related features.[3]

PRIMARY SENSING TECHNIQUES: Visual (color) imaging[1,3]
Radar imaging[2,3]

SUPPLEMENTARY SENSING TECHNIQUE: IR imaging[3]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Visual Imaging	6-30m[1] 3-30m[3] 15-150m[3] .03-3m[2]	3m (90m[1])
Radar Imaging	3-30m[3] .03-3m[3]	3m (90m)
IR Imaging	3-30m[3] .03-3m[3]	3m (90m)
THERMAL SENSITIVITY:		1.0°C
SUN ANGLE:	30-90° [1]	20-90°
SWATH WIDTH:	18 km[1]	18 km
LOCATION TO BE OBSERVED:		Areas affected by damaging storms.
OBSERVATION SCHEDULE:	Twice[1]-for each storm hourly during storm period.[3]	Daily until storm leaves the area.
RESPONSE TIME:		3 - 6 hours

CODE: DIS 2

OBJECTIVE: Earthquake Damage Assessment

DESCRIPTION: Provide rapid, accurate regional damage assessment of areas stricken by earthquakes.[12] Information on accessways is also important so that aid can be furnished rapidly.[1] Study geologic and topographic changes resulting from earthquakes.[1]

METHOD: Obtain visual photographs as soon as possible after a quake.[1] Radar may be useful if visibility poor due to clouds or dust,[1] but there should be much less dust with an earthquake than with a volcano.[1] IR would also be useful for spotting fires, hot springs, etc. Note changes in surface features, crustal structures, and cultural features.

PRIMARY SENSING TECHNIQUE: Visual (color) imaging[1]

SUPPLEMENTARY SENSING TECHNIQUE: Radar imaging[1]
Thermal IR imaging
Data Collection System[1]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Visual Imaging	6-30m[1] 0.3-3m[3]	3m (90m[1])
Radar Imaging	30m[1] 0.3-3m[3]	3m (90m[1])
IR Imagings	0.3-3m[3]	3m (90m)
THERMAL RESOLUTION:		1.0°C
SUN ANGLE:	Not critical[1]	20-90°
SWATH WIDTH:	18 km[1]	
LOCATION TO BE OBSERVED:		See Earthquake Belt Recon. (GLG 6) for areas where earthquakes are liable to occur.
OBSERVATION SCHEDULE:	At least daily[1] Must be immediately following the occurrence of an earthquake.[3]	Daily for up to a week after earthquakes occurrence.
RESPONSE TIME:	12 hours.[1] (for damage assessment)	

CODE: DIS 3

OBJECTIVE: Volcanic Eruption Damage Assessment

DESCRIPTION: To make rapid assessment of the extent of regional damage following a volcanic eruption.[1,12,50] To inventory new geological data to maintain baseline information (monitor topography changes). Update area maps[1] and warn off new eruption channels.[1] Provide rapid prediction of routes of lava advance.[1] Assessment of damage during and after eruption could save critical time in planning, obtaining support and acquiring appropriate supplies.[3]

METHOD: Locate lava flows, ash flows, vents--by color or IR imaging.[3] Note damage to existing cultural features.[3] Use IR to warn of new eruption channels.[1] IR would spot hot springs.[1,15] Radar would be used as backup in case visibility observed by dust, clouds, etc.[1]

PRIMARY SENSING TECHNIQUE: Visual (color) imaging[1,3]

SUPPLEMENTARY SENSING TECHNIQUE: IR imaging,[3,12] 4.5 - 5.3 and 8 - 12 [1]
Radar imaging[1]
Data collection system[3]

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:		
Visual Imaging	6m[1] 3-30m[3] 0.3-7m[3] 30-300m[3]	3m (90m[1])
Radar Imaging	6-30m[1] 3-30m[3]	3m (90m)
IR Imaging	150-300m[1] 30-300m[3]	30 (300m)
THERMAL RESOLUTION:	$1^{\circ}C$[1]	
SUN ANGLE:	Not critical[1]	20-90
SWATH WIDTH:	18 km	
LOCATION TO BE OBSERVED:		Wherever an eruption takes place - for the U.S most probably in Calif., Oreg., or Wash.
OBSERVATION SCHEDULE:	Every 24-48 hours[1] During eruptions	
RESPONSE TIME:	3-6 hours[1]	

CODE: DIS 4

OBJECTIVE: Flood Damage Assessment

DESCRIPTION: Rapid and complete assessment of conditions existing during floods can be of great value in organizing and planning relief measures for stricken areas. Such information is often difficult to obtain on the ground due to breakdown of transportation networks and of communications. The information would be of assistance also in providing warnings for down-stream areas of approaching flood conditions.

METHOD: Information would be desired on the degree of flooding and the extent of resultant damage. The high likelihood of clouds over flooded areas places a premium on the use long-wave length imaging systems which can provide penetration.

PRIMARY SENSING TECHNIQUES: Radar imagery
Color or black-and-white visual imaging

ALTERNATE SENSING TECHNIQUES: Thermal IR imagery

MEASUREMENT PARAMETERS:		RECOMMENDED VALUES
GROUND RESOLUTION:	6-15 m[1]	
THERMAL RESOLUTION:	1.0 C[1]	
SUN ANGLE:	30[1]	20[1]
SWATH WIDTH:	45[1] km	
LOCATION TO BE OBSERVED:		Major river systems
OBSERVATION SCHEDULE:	Once per 1-3 days, minimum Once per orbit[2]	Daily
RESPONSE TIME:	24 hrs[1]	one day

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